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# A COMPARATIVE STUDY OF THE WATERWAYS AND OLDER FORMATIONS OF THE McMURRAY AREA

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W.D. MacDonald

April - 1947

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# A COMPARATIVE STUDY OF THE WATERWAYS AND OLDER FORMATIONS IN THE McMURRAY AREA, ALBERTA

by

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Edmonton, Alberta April, 1947

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The undersigned hereby certify that they have read, and recommended to the Committee on Graduate Studies for acceptance, a dissertation on "A Comparative Study of the Waterways and Older Formations in the McMurray Area, Alberta", submitted by William Delbert MacDonald, B.Sc., in partial fulfilment of the requirements for the degree of Master of Science.

## Table of Contents


Chapter I — Page

Introduction

I General Statement ..... 1

II Acknowledgments ..... 1

III Location and Accessibility ..... 2

IV Salt Industry at McMurray and Waterways ..... 3

V History and Previous Work Done .... 4

Chapter II

I Summary and Conclusions ..... 7

Chapter III

The Technique and Examination of Well Samples

I General Statement ..... 10

II Methods of Drilling Wells ..... 10

III Collection and Labelling of Samples 11

IV Disintegration of Samples ..... 12
1. General Statement ..... 12
2. Methods of Disruption ..... 12
3. Conclusion ..... 13

V Methods of Mineral Isolation ..... 14
1. Acid and Decantation Separation ..... 14
2. Horseshoe Magnet ..... 15
3. Heavy Liquids ..... 15

VI Identification of Minerals ..... 15

1. The Optical Method ..... 16
(1) Gypsum and Anhydrite .. 16
(2) Calcite and Dolomite .. 16
(3) Salt ..... 17
(4) Marcasite ..... 17
2. Acids ..... 17
(1) Limestone and Dolomite. 17
(2) Anhydrite ..... 17
(3) Marcasite ..... 18
3. Ether ..... 18
4. Potassium Ferrocyanide .... 18
5. Blow Pipe Method ..... 18
6. The Closed Tube Method .... 18
7. Staining..... 19
(a) Methods of Staining
(1) Silver Nitrate-Potassium Chromate .... 19
(2) Ferric Chloride-Ammonium Sulphide Solution ..... 20
(3) Lemberg'd Staining Method ..... 20
(4) Fairbank's Modified Lemberg Solution ..... 21
(5) The 10 per cent Ferric Chloride Solution ..... 21
(6) The Titan Yellow Method 21
(b) Staining Methods Applied 22
(c) Conclusions Regarding Staining ..... 22

VII General Conclusions ..... 23

Chapter IV

Stratigraphy

I Table of Formations ..... 24

II General Statement ..... 24

III Detailed Well Logs ..... 24
1. The Log of the Alberta Government Salt Well No. 1. 25
2. The Log of Industrial Minerals Limited Salt Well No.1 34
3. The Incomplete Log of Industrial Minerals Limited Salt Well No. 3..... 43

IV The Precambrian ..... 48

V Upper Ordovician (Richmond) ..... 48
1. Industrial Minerals Ltd. Well No. 3 ..... 48
2. Industrial Minerals Ltd. Well No. 1 ..... 49
3. Further Evidence to Support Richmond Age ..... 50
(1) Verbata No. 2, Unity, Saskatchewan ..... 50
~~(2) Imperial-Provost Well No. 8, Provost, Alberta .... 50~~
(3) Vermilion Consolidated Oils Ltd. No. 15, Vermilion, Alberta ..... 50
(4) Red River Formation, Southern Manitoba ..... 50
(5) The Hudson Bay Region ... 51
(6) The North Arm of Great Slave Lake ..... 51
(7) Lake Nicholson, N.W.T. . 51
(8) Alaska and Yukon ..... 51
(9) Mackenzie Mountains ..... 52
(10) Tigonankweine Range ..... 52
(11) Beaverfoot-Brisco Range.. of Southeast British Columbia ..... 52
(12) Commonwealth Milk River Well ..... 52
(13) ~~Mt. Wilson and~~ Sunset Pass ..... 52
4. Conclusion ..... 53

VI Pre-Middle Silurian or Middle Silurian ?

1. Definition ..... 53
2. Local Relationships of the Pre-Middle Silurian or Middle Silurian (?) in the McMurray Area ..... 54
3. Sub-division of the Pre-Middle Silurian or Middle Silurian ..... 54
4. Distribution of the Pre-Middle Silurian or Middle Silurian (?) Series ..... 55
(1) Fort MacKay Well ..... 56
(2) Athabaska Oils, Ltd. .... 56

(3) McMurray Area ..... 56
(4) La Saline ..... 56
(5) The Salt River Escarpment ..... 57
(6) Peace Point on Peace River, Alberta ..... 57
(7) Slave River Outcrops ... 58
(8) Imperial Oil Co. Well, Nintse Point ..... 58
(9) Gypsum Point, Great Slave Lake ..... 58
(10) Wrigley-Cap Mountain Section of Franklin Mountains, N.W.T. ..... 59
(11) Bear Rock Section, Fort Norman ..... 59
(12) Carcajou and Norman Range 59
(13) Vermilion Ridge Well No. 1, Norman Wells, N.W.T.. 60
(14) Vermilion, Alberta ..... 60
(15) Unity Valley Well No. 2, Unity, Saskatchewan .... 60
(16) Verbata No. 2 Well, Unity Saskatchewan ..... 61
(17) Manitoba Section, Lake Winnipeg Region ..... 61
(18) Deep Wells in Manitoba . 61
(19) North Dakota ..... 62
5. Generalizations from this Evidence ..... 63

VII Middle Silurian ..... 65
1. Definition ..... 65
2. Middle Silurian at McMurray and Waterways ..... 65
3. Evidence for Middle Silurian Age ..... 66
(1) Kindle's Peace Point Section ..... 66
(2) La Butte Section ..... 67
(3) Stony Island Section ... 68
(4) Gypsum Point ..... 68
(5) Clearwater River ..... 69
4. Conclusion ..... 69

VIII The Upper Devonian ..... 69
1. Definition ..... 69
2. The Waterways Formation at Waterways and McMurray .... 70

Chapter V

Petrology and Petrography


I General Statement ..... 73

II Alberta Government Salt Well No. 2 (785'-789') ..... 73

III Alberta Government Salt Well No. 2 (781'-785') ..... 74

IV Bottom of Industrial Minerals Limited Well No. 3 (952') ..... 75

V Well No; 3 (938'-952') ..... 76
1. Mottled Dolomitic Limestone. 76
2. Observations ..... 76
3. Classification of Dolomitic Limestone ..... 78
(1) Primary Deposition of Dolomitic Limestone ..... 78
(a) Deposition as Clastics 78
(b) Deposition by inorganic Chemical Processes ..... 78
(c) Deposition by Organic Chemical Processes ... 79
(2) Secondary Deposition of Dolomitic Limestones .... 80
4. Application of Theories to No. 3 Well ..... 81
5. Factors of Doubt ..... 82
6. Conclusion ..... 82

VI Cottee No. 1 Well Pre-Middle Silurian or Middle Silurian Section ..... 83
1. Environmental Conditions ... 83
2. The Concept of Deposition of Saline Residues ..... 83
3. Observations Regarding Saline Deposits in Cottee No. 1 Well 84
(1) Microcrystalline Dolomite 84
(2) Rock Salt ..... 85
(3) Dolomitic Red Beds ..... 85
(4) Satin Spar Veining ..... 86
(5) Anhydrite Veining ..... 87
(6) Brown Selenite Replacements ..... 87

(7) Rock Gypsum ..... 88
(8) Limestone and Dolomitic Limestone ..... 88
4. Conclusions ..... 88

VII Middle Silurian in Cottee No. 1 Well ..... 90

1. Environmental Conditions ... 91

VIII Waterways Formation in Cottee No. 1 Well ..... 91
1. The Lower Limestone (485'-490') ..... 91
2. Calcareous Shale ..... 92
3. Mottled Limestone and Argillaceous Limestone ..... 93
4. Stylolites ..... 93
5. Marcasite ..... 94
6. Nodules ..... 95
7. Calcite Veining ..... 96
8. Charophyte Oogonia (Trochiliscids) ..... 96

IX Bibliography ..... 98

Maps and Illustrations

Map No. 1 - Geology of the McMurray Area ..... Pocket
Map No. 2 - Key map of Alberta and map of McMurray Area Well Positions ..... Pocket
Log No. 1 - Alberta Government Salt Well No. 1 ..... Pocket
Log No. 2 - Industrial Minerals Ltd. Salt Well No. 1 ..... Pocket
Table No. 1 - Correlation of Fauna and Flora in the Waterways Formation at Waterways and McMurray ..... Pocket
Table No. 2 - Correlation of the Waterways Formation with Portage Naples Age in Other Parts of North America ..... Pocket

# Chapter I

## Introduction

### General Statement

Two complete and one incomplete salt well cores from the salt wells at McMurray and Waterways were examined in detail. These cores were from:

1. The Alberta Government Salt Well No. 1, McMurray, Alberta.
2. The Industrial Minerals Limited Cottee Well No. 1, Waterways, Alberta.
3. The incomplete core of the Industrial Minerals Limited No. 3, Waterways, Alberta.

The purpose was to determine the kind of sediments and their age.

This study was restricted to the Paleozoics. In the McMurray area this consisted of the sediments from the Precambrian up to and including the Upper Devonian Waterways formation.

Widespread correlations were used only for the purpose of strengthening age assignments given.

### Acknowledgments

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of this thesis, the writer is greatly indebted. To Dr. J. A. Allan who suggested this problem and under whose guidance this thesis has been prepared, I wish to express my thanks for kindly advice and criticisms. I wish to thank Dr. P. S. Warren for his valuable help in identifying fossils, and for his helpful suggestions. To Dr. R. L. Rutherford the writer expresses appreciation for guidance in sedimentary petrology. I wish to thank Mr. M. B. Crockford for his assistance. To Mr. J. Groot I wish to express my appreciation and thanks for drafting done. I thank Mrs. V. Stover for typing the logs of two wells.

The writer relied upon the library facilities of the University of Alberta and the library of the Department of Geology. For these conveniences the writer wishes to express his gratitude.

## Location and Accessibility

The McMurray Area, Alberta, is the one under consideration. The specific area is at the confluence of the Athabaska and Clearwater Rivers. Map 2 shows the location of the salt wells in this area. Both McMurray and Waterways lie within township 89, range 9, west of the 4th meridian, latitude 56. McMurray is about 240

miles northeast of Edmonton, Alberta, by air route. The end of the steel of the Northern Alberta Railway is at Waterways, a distance of 304 miles from Edmonton. Waterways is 3 miles up the Clearwater River from its junction with the Athabaska River. Canadian Pacific Airlines have an airfield at Waterways, and a sea base at McMurray. Canadian Pacific Airlines provide mail and passenger service from Edmonton to Waterways. During the summer season the Hudson Bay Transport does a freighting business downstream from McMurray to Aklavik on the Mackenzie River delta.

Salt Industry at McMurray and Waterways

Attempts to establish a salt industry go back to 1907, while salt has been produced commercially since 1936. The latest salt well development took place in 1939 at Waterways. This operation was carried out by Industrial Minerals Limited. Industrial Minerals Limited Salt Well No. 3 is located about 500 feet southwest from the salt plant at Waterways (see Map 2). Surface elevation at this well is 853 Feet above sea level.

Cottee No. 1 Well was drilled by Industrial Minerals Limited in 1936. It is located 589 feet southwest of Waterways station (see Map 2).

A No. 2 and a No. 4 well also have been drilled by this company.

In 1919 the Alberta Government Salt Well No. 1 was started on Lot No. 8 of the McMurray townsite (see Map 2). Three years later the Alberta Government drilled No. 2 Well on the N.W. ¼, Sec. 32, Tp. 88, R. 8, West of the 4th Meridian. This is near Draper at the confluence of Deep Creek and Clearwater River. (See Map 2).

Still earlier the Northern Alberta Exploration Company drilled two wells at the mouth of Horse River. The first well was drilled in 1907 and the second in 1912.

In 1924 a grainer plant was built by the Alberta Salt Company Limited to manufacture salt from brine. This venture proved unsuccessful.

History and Previous Work Done

The history of the McMurray area commenced ~~back~~ in 1778 when Peter Pond reached the Athabaska River by way of Methys Portage and the Clearwater River. He was followed by Phillip Turner who surveyed the Athabaska River below the mouth of the Clearwater during the years 1790-92,(14)

In 1793 Sir Alexander Mackenzie passed through the McMurray area on his way up the Peace River.

During the years 1799-1803 David Thompson surveyed the Athabaska River System from Lesser Slave Lake to the Clearwater Forks (74). In 1819 Franklin described the area between the Clearwater Forks and the Lake Athabaska (30). W. D. Harmon (5) in his "A Journal of Voyages and Travels in the Interior of North America", 1820, reported on the physical features of the McMurray area. Richardson (58), Back (8), and Simpson (65) described this region. They passed through on the way to the Arctic. Dr. Selwyn (63), Director of the Geological Survey, mapped and reported on the Upper Peace River in 1875, while his assistant, Professor Macoun, returned to the east by way of the Athabaska and Clearwater Rivers.(46)

In 1882 Dr. R. Bell made a geological survey of the Athabaska River below the mouth of Lac La Biche River to the Clearwater River (12). William Ogilvie carried out a micrometer survey of the Lower Athabaska River in 1884 (54). R. G. McConnell (1887) gave the most complete report on the McMurray region to this time. Camsell (17) (1902) also reported on the area. Wyatt Malcolm (1913) (47) summarized the work done by earlier men in this area. S. C. Ells (28) carried on extensive work in the McMurray area with bituminous sands from 1913-1925. McLearn (1916) (49) described sections along the Athabasca River near

McMurray. In 1919 Dr. J. A. Allan (1) did field work in the McMurray area and recommended that the Provincial Government drill in the vicinity of McMurray. This was done. Allan also located the Alberta Government No. 2 Salt Well near Draper in 1921,(2).

McMurray Salt was described by Allan in 1929 (3) and by Cole in 1930 (22). Warren (1933) examined and determined the age of fossils collected by Dr. J. A. Allan and Dr. K. A. Clark from limestone outcrops along the Athabaska and Clearwater Rivers. He gave the name Waterways formation to this Upper Devonian limestone which carried a Portage fauna.

Many oil geologists have investigated the bituminous sands. Among them were Hume, Sproule, Bell, Slipper, Dowling, Moore, Clark, Blair and Russel, (see bibliography).

## Chapter II

### Summary and Conclusions

(1) The McMurray area as shown on the key map (Map 2) is underlain by Precambrian, Paleozoic, Mesozoic, beds, while a mantle of unconsolidated deposits (River gravels, sands, silts, etc., in the Clearwater Valley and glacial deposits on the uplands) of Recent age form the surface.

(2) The writer believes that the lowermost 14 feet of the Industrial Minerals Limited Salt Well No. 3 is Upper Ordovician. Fauna, lithology, and the paleogeographic trend of the Upper Ordovician Sea is given as evidence even though the amount of core samples available was small for such a determination.

(3) The age of the salt is somewhere between Upper Ordovician and Middle Silurian.

(4) A 3 to 5-foot bed of Middle Silurian occurs in the salt wells at McMurray and Waterways, Alberta. Evidence is the lack of lithological relationship to the sediments above and below, the lithological similarity to Middle Silurian beds in Lake Athabaska to Great Slave Lake region, and the discovery of a Guelph (Middle Silurian

fauna on the Clearwater River east of McMurray, Alberta.

(5) No Lower or Middle Devonian was found at Waterways and McMurray.

(6) The Waterways formation is Upper Devonian and Portage-Naples in age.

(7) As far as the writer could discern great time breaks show no expected erosional features. It may be that no deposition and no erosion took place. One exception is thought to be the Middle Silurian-Rock Gypsum contact.

(8) There is apparently no porosity in the Waterways formation at Waterways and McMurray, Alberta. This limestone is dense. The writer could find no indications that would suggest porosity in adjacent areas.

(9) No primary gypsum could be found at Waterways and McMurray. It occurs as altered anhydrite or as satin spar veins and interbeds. This altered anhydrite or rock gypsum is limited to the uppermost 3-5 feet of the evaporite series. There is evidence to indicate that this rock gypsum was a cap rock and probably an erosional surface. No lower horizons of rock gypsum were found.

(10) The origin of the dolomite in the evaporite

series could not be proved.

(11) The source of the iron in the dolomitic red beds could not be determined.

(12) Secondary anhydrite veining occurs.

(13) Epithermal calcite and marcasite veining occur.

(14) Marcasite was formed subsequent to deposition of the limestone and calcareous shale.

(15) The nodules examined were contemporaneous with deposition.

Chapter III

# THE TECHNIQUE AND EXAMINATION OF WELL SAMPLES

## I. General Statement

The purpose is to give a brief outline of possible methods and those used in the identification of the sedimentary rocks and their mineral constituents with respect to the following salt wells cores:

1. The Alberta Government Salt Well No. 1, McMurray, Alberta.
2. The Industrial Minerals Limited Salt Well, No. 1, Waterways, Alberta.
3. The Industrial minerals Limited Salt Well, No. 3, Waterways, Alberta.

The first two well cores were fairly complete, while only intermittent sections of core were available for No. 3.

## II. Methods of Drilling Wells

The following three methods are common:

1. Diamond core drilling.
2. Percussion drilling.
3. Rotary drilling.

Of these three, the diamond core drilling is the best for preserving good rock specimens. It produces a solid cylinder of rock, preserving bedding and other

features of the section. Complete or fairly complete macrofossils can be obtained from a core.

The second, percussion drilling, produces rock fragments or bit fragments. These are satisfactory for the examination of mineral and microfossil content. This method destroys macrofossils, bedding planes, and other features.

The third method, rotary drilling, yields bit cuttings or rock fragments. Drilling mud carries or floats these cuttings to the surface where they must be washed before examination. This is the poorest method of obtaining good samples.

The writer was fortunate to have diamond drill cores of the sediments from Waterways and McMurray salt wells. Such features as the kind of bedding, the facies changes, the fossil horizons, veining and so on, could be determined.

## III. Collection and Labelling of Samples

Samples were collected from every facies change observed in the three well cores. These samples were placed in metal-capped glass vials 2½" X 3/4" in size. Labels giving data as to the particular well, the depth,

and the kind of sedminetary rock were glued upon these vials. This data was written on the labels with an indelible pencil. Within the vials are typewritten slips giving the depth from which the sample was taken.

Fossil samples from the various fossil horizons in these cores were placed in trays and labelled as to the depth from which they came. These fossil specimens were identified and the specimens were discarded except for a few specimens such as the conodants, fish jaws and Trochiliscids.

## IV. Disintegration of Samples

### 1. General Statement

Disruption to preserve grain size was unnecessary since the sediments in the samples were nonclastic. However, several methods of disruption were attempted in order to separate fossils from mottled limestone and argillaceous limestone matrix.

### 2. Methods of Disruption

The following methods were tried:

(1) the use of such tools as the rock splitter, the geological hammer, the nippers, a sharp small stylus for finer work.

(2) heating the limestone to a dull redness and

then plunging it into cold water.

(3) the saturation of the limestone with sodium carbonate solution and then plunging it into acid. The theory was that the pressure of the evolving carbon dioxide gas would aid in freeing the fossils from the limestone.

(4) The use of NaOH and KOH to digest argillaceous material in the limestone and thereby assist in the separation of the fossils from the limestone matrix.

(5) The use of ammonium nitrate saturated solution (44). A cold solution will dissolve 117 grams of ammonium nitrate per liter. A solution brought to a boil will take in 1100 grams of ammonium nitrate per liter. If a fossiliferous limestone sample were boiled for five minutes in such a saturated solution, it was thought that the solution would penetrate the limestone especially along the fossil outlines. Quick cooling would cause the excess ammonium nitrate to crystallize out. In doing this it would separate the fossils from the limestone.

3. Conclusion

With the exception of the rock splitter, the geological hammer, the nippers, and the stylus, these

methods of disintegration were found impracticable for limestone. Saturation of the limestone by solutions could not be achieved within 5 or 10 minutes. Most of these solutions required hours in order to penetrate any depth into the sample.

V. Methods of Mineral Isolation

The general procedure is to take the whole sample, crush it, fraction it into quarters, then take opposite quarters, mix them, fraction them once again, and so on, until a desired fraction of sample is obtained. This is the correct procedure for clastic sediments. But since the sediments worked with were non-clastic, only small chips or fragments were taken, crushed, and mineral isolation attempted by the following methods:

1. Acids accompanied by decantation.
2. Horseshoe magnet.
3. Heavy liquids.

1. Acid and Decantation Separation

Hydrochloric acid was used to remove the limestone from calcareous shale and argillaceous limestone. These, the acid and the limy sample, were placed in a tall measuring cylinder. When the reaction was complete the residue was washed several times with water. The

water was then decanted off as well as some of the finer clay minerals. The residue was fried and examined by optical means.

2. Horseshoe magnet

A horseshoe magnet was passed over the clay mineral residue which had either been placed on a watch glass for this test. No minerals were attracted to the magnet. This magnet was also passed over imersion mounts of these clay residues to see if any magnetic minerals were present.

3. Heavy liquids

These were discarded because it was found that immersion mounts of crushed samples were more satisfactory for mineral determinations.

VI. Identification of Minerals

The following methods of mineral identification were used:

1. The optical method by means of a petrographic microscope.
2. Acids (Hydrochloric and Nitric).
3. Ether.
4. Potassium ferrocyanide.
5. Blowpipe method.

6. Closed tube method.

7. Staining.

1. The Optical Method

This method was the most reliable. The index of the mineral and the angle of extinction were sufficient to determine most minerals.

(1) Gypsum and Anhydrite

Gypsum was determined on the basis of color, low positive index and angle of extinction. Anhydrite, on the other hand, was determined by rectilinear cleavage flakes, index from 1.57 to 1.61, and parallel extinctions.

(2) Calcite and Dolomite

These two are the most difficult to determine. Their indices are relatively near each other, namely,

calcite w = 1.658 . e = 1.486

dolomite w = 1.68z . e = 1.503

Both blink upon rotation of the stage. Both have high order interference colors.

However, the writer believed that these minerals could be distinguished on the basis of habit. Dolomite appeared as a microcyrstalline aggregate with definite rhombohedral habit. Grain size was approximately 1/200 mm. Calcite did not express this rhombohedral habit nor did it aggregate. Lammelar effect was noticeable

especially in vein calcite. A mosaic pattern was a common feature of most of the limestone.

(3) Salt

The salt index was about the same as Canada balsam immersion liquid. Only a faint yellow-orange border was observable about the square salt grains. Under crossed nicol the salt was extinct.

(4) Marcasite

This mineral was generally determined with the use of binoculars. It expressed either arrowhead twinning or a twinned aggregate.

2. Acids

Hydrochloric acid was used to assist in determining limestone, dolomite and anhydrite. Nitric acid was used to test marcasite

(1) Limestone and Dolomite

Limestone and calcite effervescent freely in dilute cold hydrochloric acid while the microcrystalline dolomite effervesced slowly. Crystalline replacement dolomite required heat to cause effervescence. Dolomitic limestone showed moderate vigor.

(2) Anhydrite

Anhydrite produced no reaction in cold or

heated dilute hydrochloric acid. However, when anhydrite was immersed in hot concentrated hydrochloric acid, the reaction was vigorous.

(3) Marcasite

A 15% solution of Nitric acid caused marcasite to react.

3. Ether

Ether was used to identify bitumin. A crushed sample of bituminous limestone was washed about in ether on a watch glass upon the complete evaporation of the ether, a slight oil ring was on the watch glass.

4. Potassium Ferrocyanide (31)

The immersion of maroon and green-grey dilute acid potassium ferrocyanide gave a light bluish-white precipitate. This proved the presence of ferrous iron and accounts for the maroon splotched dolomite.

5. Blow Pipe Method

The blow pipe was used to determine if siderite was matrix of nodules found in the well cores. No iron test resulted and it was concluded that the matrix was limestone.

6. The Closed Tube Method

The closed tube was employed to determine the presence of gypsum. Heat was applied to a tube containing sampled thought to contain gypsum. If water condensed in the upper part of the tube, then gypsum was present.

7. Staining

Several methods of staining have been advanced for the differentiation of dolomite from limestone. Among these are the following:

(1) Silver nitrate-potassium chromate solution.

(2) Ferric chloride-ammonium sulphide solution.

(3) Lemberg's solution.

(4) Fairbank's Modified Lemberg's solution.

(5) The 10 per cent Ferric chloride solution.

(6) The Titan yellow solution.

Otto ( 44) who had investigated all the known methods of staining, concluded that the silver nitrate-potassium chromate was the best.

(1) The Silver Nitrate-Potassium Chromate Method

This method required a 10 per cent solution of silver nitrate, Powdered or broken surfaced calcite or dolomite was immersed for 2 - 5 minutes. It was then washed thoroughly with distilled water to remove the excess silver nitrate. This water was decanted off. A neutral solution of potassium chromate was prepared and

poured upon the sample. After one minute the sample was again washed in distilled water. Calcite stained brown, white crystalline dolomite remained colorless. Microcrystalline dolomite stained a somewhat lighter brown than the calcite.

(2) Ferric chloride - Ammonium Sulphide Solution

Steidtmann ( 72 ) discovered that if a fresh broken or ground surface of calcite or dolomite was first wetted with water and then immersed in a 2½ per cent solution of Ferric chloride for 10-15 seconds, the excess washed off, then immersed in ammonium sulphide for 10-15 seconds and the excess washed off, the calcite would stain black and the dolomite would not stain.

(3) Lemberg's Staining Method

Lemberg's ( 29 ) staining method was used with variable results. It was prepared by boiling the following constituents for 25 minutes:

6 parts logwood chips
4 parts aluminium chloride
60 parts water.

Too many variable factors make this solution unsatisfactory. Time, concentration and variable amounts of haematoxylin obtained from the logwood are among these factors.

(4) Fairbanks' Modified Lemberg Solution ( 29)

Fairbanks' solution is as follows:

0.24 grams haematoxylin
1.6 grams aluminum chloride
24 grams water

This solution was brought to a boil and then cooled. A small amount of hydrogen peroxide was used to oxidize the haematoxylin to hematein.

Calcite and dolomite are immersed in the cold staining solution for 5 minutes. The solution is washed off. As a result, calcite is stained, while, dolomite is not.

(5) The 10 per cent Ferric Chloride Solution

Douglas, King and Misick (25 ) found that a 10 per cent solution of ferric chloride by weight was useful in dolomite and calcite determinations. The solution is applied for 1 minute or so. Limestone effervesced slowly and the surface encrusted. When the specimen was washed off the limestone showed a brown stain. Dolomite showed no stain.

(6) The Titan Yellow Method

Douglas, King and Misick ( 25) found that Titan yellow could be used successfully in the laboratory. The mineral is first powdered, then placed in a test tube

with 5 c.c. of distilled water. To this is added 3 c.c. of 0.1 per cent by weight titan yellow solution. The mixture is well shaken. Added to this is 2 -3 c.c. of 0.1 N. of potassium hydroxide solution. This is boiled, cooled and the residue examined for change of color. If the residue turned red, then magnesium is present. The degree of color then would indicate the amount of limestone and dolomite present.

(7) Staining Methods Applied

The writer used the following staining methods:

(1) Silver nitrate-potassium chromate
(2) Ferric chloride-ammonium sulphide
(3) The 10 per cent Ferric chloride solution.

The others were not used. With the exception of Titan yellow, the principles involved in the others were the same as those used. Lack of time also prevented further experimentation.

(8) Conclusions Regarding Staining

The writer found the following evidence with regard to staining:

(1) Crushed limestone stained as expected.

(2) Chips of argillaceous limestone sometimes stained in splotches. The application of acid to both stained and unstained seemed to have equal effervescence.

(3) Crystalline dolomite when tested remained

unstained except along fractures.

(4) The microcrystalline dolomite, the characteristic type of dolomite, in the Waterways salt wells stained almost as deeply as limestone. This may be due to the stain filling in and about the aggregate microcrystalline mass of dolomite.

Staining methods were therefore unreliable.

## VII. General Conclusion

As a result of this study it was found that the most reliable method so far discovered is the optical method.

Chapter IV. - Stratigraphy.
I. Table of Formations.

| ERA | PERIOD | FORMATION | DESCRIPTION | MINIMUM THICKNESS | MAXIMUM THICKNESS |
|---|---|---|---|---|---|
| Cenozoic | Recent | | Alluvial clays, silts sand, boulders, limy rubble and disintegr-rated shale from the Devonian. | 40 ft. | 106 ft. |
| Mesozoic | Lower Cretaceous | McMurray sandstone | Partially eroded away in the Clearwater Valley. Present at the No.3 Well.<br>Bituminous sand<br>Soft shale | 0 ft. | 33 ft.<br>76 ft. |
| | E R O S I O N A L S U R F A C E | | | | |
| Paleozoic | Upper Devonian | Waterways Formation | Limestone, argillaceous and mottled, buff-grey, fossils; calcareous shale, green-grey, fossils; limestone, brown, dwarf fauna. | 364 ft. | 402 ft. |
| | D I S C O N F O R M I T Y | | | | |
| | Middle Silurian | | Limestone and dolomitic limestone, platy, thin-bedded, creamy to dark brown, fractured, calcite veined, bituminous, non-fossiliferous. | 3 ft. | 5 ft. |
| | U N C O N F O R M I T Y ? | | | | |
| | Pre-Middle Silurian or Middle Silurian? | | Rock gypsum; dolomite, dolomitic anhydrite, anhydritic dolomite, satin spar veins and interbeds, dolomitic red beds, rock salt. | 182 ft. | 418 ft. |
| | Upper Ordovician | | Dolomitic limestone buff to brown mottled porous, bituminous banded dwarf fauna. | 1 ft. | 14 ft. |
| | (?) | | Breccia | 4 ft. | |
| | E R O S I O N A L U N C O N F O R M I T Y | | | | |
| Precambrian | | | Granite, dark grey, Pyritic. | 4 ft. | |

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## Chapter IV

### II General Statement

This report deals only with the Paleozoic strata as described herein in the logs of the salt wells of McMurray and Waterways. A geological map of the McMurray area of Alberta with scale 1 inch to 6 miles shows outcrops of these Paleozoics. This map is enclosed in a pocket at the back of this report. Upper Devonian tables Nos. 1 and 2 also are enclosed in the same pocket, as are the logs of the Alberta Government Salt Well No. 1, and the Industrial Minerals Limited (Cottee Well) No. 1.

### III Detailed Well Logs.

Detailed geological logs showing the succession of the sediments in 3 salt wells at McMurray and Waterways are as follows:

## LOG OF ALBERTA GOVERNMENT SALT WELL NO. 1

## McMURRAY ALBERTA

Surface elevation, 795 feet above sea level.

| Depth in feet | Description |
|---|---|
| 0-13 | - Loose dirt |
| 13-16 | - Quicksand |
| 16-42 | - Alluvial mud, blue |
| 42-55 | - Sand, white silica |
| 55-60 | - Sand and boulders |
| 60-78 | - Limestone argillaceous |
| 78-95 | - Crevice sand and boulders |

Top of Waterways Formation

| | |
|---|---|
| 95-96 | - Limestone, lithographic, colorless calcite replacements, and shell replacements, marcasite veining. |
| 96 | - 2" band of limestone, soft, grey, irregularly compacted, fossiliferous<br>Crinoid stems<br>Atrypa devoniana Webster<br>Spirifer allani Warren |
| 96-105 | - Limestone, buff-brown, with thin inter-bands of brown grey arg. limestone, fossiferous. Brown limestone contains colorless crystalline calcite replacements |
| 105-110 | - Limestone, argillaceous, brownish-grey, irregularly compacted |
| 110-120 | - Limestone grey-brown, massive, colorless, crystalline, calcite veining and replacements |

120-133 - Limestone, mottled with buff-brown and arg. brown-grey limestone, calcite replacements in buff-brown, disseminated marcasite in arg. limestone, stylolitic, fossiliferous.

131 - Spirifer allani Warren
Crinoid stems

133-135 - Limestone argillaceous, grey-brown irregularly compacted.

135-139 - Limestone, mottled, buff-brown, calcite veins and replacements stylolitic argillaceous grey-brown limestone.

139-144 - Limestone, buff-brown, and brown-grey argillaceous limestone interbands, fossiliferous

144-155 - Limestone, argillaceous, grey-brown, massive.

155-160 - Shale, calcareous, green-grey fragmental

160 - 8" limestone, mottled with colorless crystalline calcite and shell fragments cemented in green-grey calcareous shale.
Spirifer allani Warren
Atrypa reticularis (Linn)
Crinoid stems.

161-164 - Limestone, argillaceous, and fragmental calcareous shale interbands, disseminated marcasite grains

164-223 - Shale calcareous, green-grey, fragmental, fossiliferous horizons and marcasite bands.

170 - Spirifer allani Warren
Trochiliscids

210 - arrowhead twinned marcasite.
Marcasitic to 223'.

223-230 - Limestone, grey-buff, calcite veins and colorless crystalline replacements, fossiliferous.
Atrypa devoniana Webster

Atrypa albertensis Warren
Schizophoria cf. iowensis Hall
Stropheodonta sp.

230-239 - Limestone argillaceous, buff-grey irregularly compacted, fossiliferous
Atrypa devoniana Webster
Crinoid stems
Cyrtina billingsi Meek
Stropheodonta inequiradiata Hall.
Spirorbis omphaloides Goldfuss

239-240 - Limestone, mottled, colorless to buff and grey, stylolitic, crystalline calcite replacements and veinlets, fossiliferous
Crinoid stems

240-241 - Shale, calcareous, green-grey, fragmental, fossiliferous
Crinoid stems.

241-260 - Limestone, mottled, buff and grey, colorless crystalline replacements in the buff limestone, stylolitic grey calcareous shale, fossiliferous

241-243 - Atrypa devoniana Webster
Schizophoria cf. iowensis Hall

250 - Marcasite
Stropheodonta demissa (Conrad)

257 - Stropheodonta demissa (Conrad)

260-270 - Limestone, buff, massive, fossiliferous

264 - Stropheodonta demissa (Conrad)

270 - Pelecypod - Leda ?

270-290 - Limestone argillaceous, buff-grey, dispersed twinned marcasite aggregates, fossiliferous

276 - Crania famelica H. & W.
Crinoid stems
Fish plates
Schizophoria cf. iowensis Hall

Stropheodonta demissa (Conrad)

285 - Crinoid stems
Lingula cf. ligea Hall
Schizophoria cf. iowensis Hall
(Schizophoria's partially replaced by marcasite)

292-296 - Shale calcareous, green-grey, fragmental, fossiliferous,
Crinoid stems
Productella sp.
Trochiliscids

296-315 - Limestone argillaceous buff-grey, some calcite veining, fossiliferous

301 - Schizophoria cf. iowensis Hall

307 - Trochiliscids
Atrypa devoniana Webster
Schizophoria cf. iowensis Hall
Crinoid stems

304 - Marcasitic

312-315 - Stropheodonta demissa (Conrad)
Atrypa devoniana Webster
Crinoid stems

315-386 - Shale, calcareous, green-grey, fragmental, scattered plant remains replaced by marcasite

318 - scattered twinned marcasite. aggregates

328 - Spirifer allani Warren
Atrypa devoniana Webster
disseminated marcasite

340 - Spirorbis, omphaloides Goldfuss
Atrypa, devoniana Webster
Crinoid stems
Rhombopora sp.

354 - Atrypa devoniana Webster
Crinoid stems

364 - Atrypa devoniana Wesbter

386-402 - Limestone, argillaceous, grey-brown, calcite veining and replacements, marcasite replacements.

391 - Atrypa devoniana Webster

400 - Atrypa devoniana Wesbter

402-406 - Shale, calcareous, green-grey, fragmental

406-412 - Limestone, argillaceous, grey-brown, massive.

412-419 - Shale, calcareous, green-grey, some bands becoming more calcareous.

419-428 - Limestone, argillaceous, brown-grey, some shalier bands marcasitic

428-435 - Shale, calcareous, green-grey, fragmental, fossiliferous, marcasitic
Atrypa devoniana Webster
Lingula cf. ligea Hall
Spirifer allani Warren

435-442 - Limestone, mottled, grey-brown and green-grey, calcite crystalline replacements, stylolites, fossiliferous.
Schizaphoria cf. iowensis Hall
Atrypa devoniana Webster
Atrypa sp. straight-beaked var.
Pelecyopd undet.

442-455 - Shale, calcareous, green-grey, fragmental, fossiliferous.
Lingula cf. ligea Hall

450-455 - Tentaculites mackinziensis, Fish jaw

455-457 - Limestone, argillaceous, brown-grey, stylolitic, calcite and marcasite replacements.

457-480 - Shale, calcareous, green-grey, fragmental, fossiliferous.
Leptodesma sp.
Atrypa albertensis Warren
Atrypa devoniana Webster
Fish plates

Lingula cf. ligea Hall

478-480 - Tentaculetes mackenziensis Kindle

480-485 - Shale calcareous and argillaceous, limestone interbands
Lingula cf. ligea Hall
Tentaculites mackenziensis Kindle

485-490 - Shale, calcareous, green-grey, fragmental.
Lingula cf. ligea Hall

490-497 - Limestone, massive, grey-buff, black speckled with conodonts, some crystalline limestone, also some marcasite and fossils.
Athyris sp.
Atrypa albertensis Warren
Atrypa devoniana Webster
Conodonts
Nautiloids - Orthoceras type
Paracyclas cf. elliptica Hall

497 - Upper Devonian - Middle Silurian Contact

497-500 - Limestone, buff brown and creamy, platy, fractured, calcite veined.

500 - Limestone, band, creamy, 1" thick, colloidal residue after HCl treatment.

500-502 - Limestone, dolomitic, buff, finely bedded, fractured, platy. Dark brown, platy bituminous bands.

502 - Rock Gypsum Contact

502 - Gypsum, 1" band, powdery white and grey-brown. Somewhat fibrous but irregularly arranged. Dolomite and partially replaced anhydrite present. The anhydrite is changing to gypsum.

502-503 - Limestone, dolomitic, buff, finely bedded and platy; satin spar bands; grades to buff dolomite with anhydrite veins, and anhydrite vugs which show the process of gypsum replacement.

503 - Gypsum, 1" band, white and grey-brown powdery appearing but fibrous and irregularly arranged, some dolomite.

503-505 - Rock gypsum, brown, crystalline and buff dolomite interbands.

505-510 - Dolomite, buff, fine grained banded with rock gypsum and some anhydrite showing gypsum replacement.

510-514 - Anhydrite, dolomitic, buff to brown-grey crystalline anhydrite some gypsum bands.

514-516 - Limestone, grey-buff, massive some anhydrite and gypsum present.

516-524 - Anhydrite, dolomitic, buff-grey, and crystalline, some greyer fine-grained, salty bands, interbanded with satin spar.

524 - 2" Dolomite green grey, very salty, band some anhydrite.

524-531 - Anhydrite crystalline, mottled, dolomitic and salty.

531-534 - Dolomite, buff, very fine grained with white or colorless gypsum veins and bands. Some gypsum present in the dolomite.

534-537 - Anhydrite, colorless, coarsely crystalline with dolomite, buff, very fine-grained, mottles the anhydrite.

537-539 - Dolomite, grey, salty, banded with satin spar.

539-540 - Dolomite, Gypsum, and Anhydrite mottled, salty.

540-551 - Dolomite, green-grey, very fine-grained, some gypsum and salt.

551-565 - Dolomite, brown-grey, with some green-grey salty bands, some gypsum and also satin spar bands.

565-570 - Dolomite, buff-brown, fine-grained, with

colorless crystalline, dolomite replacements.

570-571 - Dolomite, dark brown, very fine-grained, some gypsum and anhydrite.

571-575 - Anhydrite, colorless, crystalline, massive, a very small amount of dolomite present giving a buff appearance.

575-578 - Anhydrite, colorless, crystalline, with thin bands of maroon and green-grey, salty, dolomite.

578-579 - Anhydrite, dolomite, some gypsum and salt, green-grey, very fine-grained.

579-583 - Anhydrite, colorless, crystalline, cemented in brown dolomite yet banding evident.

583-585 - Anhydrite, colorless, crystalline, imbedded in maroon and green-grey salty dolomitewith some anhydrite, splotched appearance.

585-586 - Anhydrite, colorless, crystalline, some buff due to dolomite.

586-590 - Dolomite, green-grey, fine-grained, salty, some anhydrite, some satin spar veins and interbands, thickness up to 3/16".

590-625 - Anhydrite, mottled and streaked with buff to fine-grained green-grey salty dolomite. Occasional satin spar veins and interbands in the salty dolomitic grey phases.

625-626 - Dolomite, buff, fine-grained with anhydrite replacements.

626-627 - No core, saline washings.

627-630 - Anhydrite, dolomitic, brown finely crystalline.

630-635 - Anhydrite, porous, and buff, fine-grained, granular salt.

635-636 - Dolomite, buff, fine-grained, grading to salty grey-brown anhydrite.

636-641 - No core, saline washings.

641-645 - Anhydrite, salt, dolomite mixture, iron staining.

645-647 - Anhydrite, dolomitic, buff and crystalline, mottled.

647-648 - Dolomite, green-grey, fine-grained, some anhydrite, salty.

648-662 - Rock salt, colorless, crystalline, transparent, some inclusions or air spaces. Contacts irregular.

662-663 - Anhydrite, mottled with buff dolomite, banded with grey dolomite and salt.

663-666 - Dolomite, green-grey to buff, satin spar and anhydrite interbands.

666-667 - Anhydrite, mottled with brown dolomite.

667-675 - Salt, anhydrite and dolomite mottled and interbanded, some iron oxide stained anhydrite. Most salt dissolved out.

675-680 - Anhydrite, dolomitic, fine, brown, grading to mottled blue-grey and brown.

680-681 - Anhydrite, dolomitic, with irregular rock salt bands.

681-685 - Anhydrite, dolomitic, mottled blue to brownish, finely crystalline.

Bottom of well.

THE LOG OF INDUSTRIAL MINERALS LIMITED

SALT WELL NO. 1

Surface elevation is 825 feet above sea level.

| Depth in feet | Description |
|---|---|
| 0-100 | - Unconsolidated material |
| 100 | - Waterways Formation Contact with Recent |
| 100-101 | - Limestone, argillaceous, brownish grey |
| 101-105 | - Limestone, mottled, buff and grey, marcasitic, stylolitic, fossiliferous. Spirifer allani Warren Crinoid stems |
| 105-110 | - Limestone, argillaceous, narrow bands of grey-buff, and buff-grey. |
| 110-118 | - Limestone, mottled, buff and grey-brown, stylolitic, marcasitic and fossiliferous 2" crystalline colorless fossiliferous calcite at 118'. Athyris sp. Spirifer allani Warren Atrypa devoniana Webster |
| 118-125 | - Limestone Argillaceous, grey-buff, with green-grey calcareous shale, Some calcite replacements in the limestone. Very marcasitic at 123'. |
| 125 | - 4" limestone, mottled, crystalline and buff band. |
| 125-130 | - Shale, calcareous, green-grey, fragmental, twin aggregates. |
| 130-140 | - Limestone argillaceous, brown-grey, and calcareous shale, green-grey interbedded, some calcite, veining. |
| 131 | - Coral, Pachypora type |

140-157 - Limestone, argillaceous, buff-grey, and calcareous shale, green-grey, fragmental, interbedded.

140 - Limestone, brown, crystalline

147 - 2" Limestone, mottled, brown, crystalline, and argillaceous brown-grey, foss.

157-160 - Limestone, brown, crystalline and argillaceous limestone brown-grey, mixed, fossiliferous.
Atrypa devoniana Webster
Conodonts
Crinoid stems

160-170 - Limestone, argillaceous brownish green-grey, and calcareous shale, green-grey interbands

170-213 - Shale, calcareous, green-grey, fragmental, marcasitic.

213-249 - Limestone, mottled, grey-brown and grey, stylolitic, marcasitic, and fossiliferous.

213-229 - Atrypa devoniana Webster
Atrypa albertensis Warren
Bryozoa
Cyrtina billingsi Meek
Schizophoria cf. iowensis Hall
Stropheodonta sp.
Crinoid stems

237 - Atrypa albertensis Warren
Atrypa devoniana Webster
Crinoid stems
Productella sp.
Stropheodonta demissa (Conrad)

249-277 - Limestone, argillaceous, grey-brown, marcasitic, fossiliferous.

249-254 - Atrypa devoniana Webster
Crinoid stems
Stropheodonta demissa (Conrad)
Stropheonella sp.

265 - Atrypa devoniana Webster

Chonetes sp.
Crinoid stems
Productella sp.
Stropheodonta demissa (Conrad)

271-277 - Atrypa devoniana Webster
Pelecypod
Pugnax pugnus (Martin)
Schizophoria cf. iowensis Hall
Stropheodonta demissa (Conrad)
Stropheonella sp.

277-285 - Shale calcareous, green-grey, fossiliferous

282 - Atrypa devoniana Webster
Lingula cf. legea Hall
Schizophoria cf. iowensis Hall
Stropheodonta demissa (Conrad)
Crinoid stems.

285-294 - Limestone, argillaceous grey-brown and calcareous shale interbeds, marcasitic, fossiliferous.
Lingula cf. ligea Hall
Schizophoria cf. iowensis Hall

294-304 Limestone, mottled, colorless crystalline, and brown argillaceous, fossiliferous.

294-300 - Strypa devoniana Webster
Crinoid stems
Cyrtina billingsi Meek
Schizophoria cf. iowensis Hall
Spirifer allani Warren
Stropheodonta demissa (Conrad)
Stropheonella sp.
Trochiliscids

304-306 - Shale, calcareous, green-grey fragmental

306-310 - Limestone, mottled, grey-brown and grey, fossiliferous.
Atrypa devoniana Webster
Stropheodonta sp.

310-381 - Shale, calcareous, green-grey, fossiliferous and marcasitic bands.

310 - marcasite twins, scattered.

310-314 - Atrype devoniana Webster
Stropheodonta sp.

322 - Atrypa devoniana Webster
Crinoid stems
Spirifer allani Warren

325 - Algae

331 - 4" band
Atrypa devoniana Webster
Crinoid stems
Fish plates

338 - Atrypa devoniana Webster
Crinoid stems
Cyrtina billingsi Meek
Styliolina fissurella Hall

345-351 - Atrypa devoniana Webster
Cyrtina billingsi Meek
Spirifer allani Warren

354 - Atrypa devoniana Webster

357 - 6" limestone, mottled, fossiliferous with calcareous shale

364 - 4" marcasitic fossil band.

368 - Atrypa devoniana Webster
Crinoid stems
Cyrtina billingsi Meek
Fish plates
Leptodesma ?
Spirifer allani Warren
Much marcasitic replacement of these fossils

378 - Atrypa devoniana Webster
Lingula cf. ligea Hall
Orbiculoidea sp.

381-416 - Limestone argillaceous, grey-brown, with thin interbeds of calcareous green-grey shale, fossils scarce, and marcasite replacements.

416-418 - Shale, calcareous, green-grey, marcasitic, and fossiliferous

Crinoid stems
Cyrtina billingsi Meek
Leptodesma sp.

418-419 - Limestone argillaceous, grey-brown, marcasitic.

419-428 - Shale, calcareous, green-grey, marcasitic, and very fossiliferous
Atrypa devoniana Webster
Atrypa, straight beaked var.
Crania famelica H. & W.
Cyrtina billingsi Meek
Leptodesma sp.
Lingula cf. ligea Hall
Modiomorpha ?
Spirifer delthyris

428-432 - Limestone argillaceous, brownish green-grey, and fossiliferous, calcareous shale interbeds.
Leptodesma sp.
Lingula cf. ligea Hall

432-445 - Shale, calcareous, green-grey, fragmental
Leptodesma sp.
Lingula cf. ligea Hall
Atrypa devoniana Webster
Cyrtina billingsi Meek

445-447 - Limestone, mottled, brown to green-grey, stylolitic with marcasite disseminated along the stylolitic faces.

447-484 - Shale, calcareous green-grey, fragmental, fossiliferous.
Atrypa devoniana Webster
Leptodesma sp.
Lingula cf. ligea Hall

452 - Nodules, limestone, irregular, elongated, flattened, no internal structure, some grains of marcasite.

460 - Nodules, limestone, circular, discordal, Calcareous shale coating, amorphous structure, some marcasite grains in the limestone. Tentaculites machenziensis Kindle ore abundantly present on the nodule coating.

460-478 - Tentaculites mackenziensis Kindle.
Leptodesma sp.
Lingula cf. ligea Hall
Fish plates.

484-485 - Shale, calcareous, greenish-brown, platy, ripple-marked Nodules, limestone, with twinned marcasite outer coating; fossiliferous.
Lingula cf. ligea Hall.

485-487 - Limestone, buff-brown, black speckled with conodonts, twinned marcasite replacements.

487-490 - Limestone, buff-grey, marcasite replacements fossiliferous
Nautiloids
Gastropods

490 - Contact between Upper Devonian and Middle Silurian

490-492 - Limestone, dolomitic, dark brown, platy, bituminous stained

492-493½ - Limestone, creamy to buff, deep brown crystalline gypsum replacements in the buff limestone.

493½ - Rock Gypsum Contact

493½-497 - Rock gypsum, dark brown, crystalline, some dolomite and anhydrite that is changing to gypsum, 4 thin powdery white layers on top.

497 - Satin spar band 1 inch thick

497-506 - Anhydrite with deep brown crystalline gypsum replacements, anhydrite grades to buff dolomites anhydrite.

506-507 - Limestone, buff-brown, with ½" band of satin spar and grey dolomitic salty anhydrite.

507-511 - Anhydrite, colorless, crystalline, mottled with buff dolomite and grey salty dolomite.

511-513 - Anhydrite and dolomite interbeds, some satin spar veining and banding in the grey

salty dolomite

513-518 - Dolomite, salty, dark grey-brown with both anhydrite and satin spar veining.

518-523 - Anhydrite, colorless, crystalline, mottled with buff-brown dolomite.

523-530 - Dolomite, salty, green-grey, some anhydrite lenses or globules, some satin spar interbands.

530-538 - Dolomite, salty, green-grey and maroon splotched, pink satin spar veins and interbands; some interbands of brownish dolomitic anhydrite.

538-539 - Dolomite, buff, with large pure crystalline globules of colorless anhydrite.

539-546 - Dolomite, dark brown, finely bedded, salty, satin spar veins and interbands, some anhydrite present.

546-551 - Dolomite, green-grey with maroon splotches, anhydrite common, gypsum rare.

551-555 - Anhydrite, dolomitic, grey-brown, salty, then it grades to buff dolomitic anhydrite

555-560 - Dolomite, dark brown, salty, satin spar veining, pink and colorless anhydrite inclusions.

560-570 - Anhydrite, dolomitic, splotched red and green-grey.

570-571 - Anhydrite, colorless crystalline, mottled with buff dolomite.

571-575 - Limestone, dolomitic, reddish brown, grades to dolomite, salty, green-grey, splotched with reddish brown.

575-620 - Anhydrite, colorless, mottled with dolomite, grey and salty, some satin spar veining and interbanding.

606 - 4" dolomite, grey salty band, Dolomite in

the anhydrite becomes browner and less salty toward 620.

620-622 - Limestone, dolomitic, buff.

622-624 - Anhydrite dolomitic, buff, crystalline.

624-626 - Dolomite, dark grey, salty, with some anhydrite.

626-640 - Anhydrite, finely crystalline, dolomitic, buff to bluish-grey, mottled, less bluish toward 640.

640 - ½" dolomite, grey, salty, some anhydrite

640-657 - Anhydrite, dolomitic, mottled blue-grey and buff.

657-660 - Dolomite, buff, vugs of colorless, crystalline, anhydrite, interbedded with finely crystalline dolomitic anhydrite.

660-670 - Anhydrite, dolomitic, mottled grey and brown, finely crystalline anhydrite.

670-680 - Dolomite, buff, salty, satin spar veins and interbands, some anhydrite.

680-684 - Anhydrite, colomitic, buff, crystalline

684-686 - Dolomite, buff, salty, finely bedded, some anhydrite

686-687 - Anhydrite, crystalline, mottled with buff dolomite.

687-690 - Dolomite, buff, finely bedded satin spar veins and interbands, some anhydrite and salt.

690-694 - Anhydrite, dolomitic, finely crystalline anhydrite mottled with buff dolomite.

694-893 - Rock salt, transparent, colorless.

893-897 - Anhydrite, colorless, crystalline, mottled with buff dolomite

897-898 - Limestone, buff, porous, thin bedded, with some satin spar veins and interbands.

THE LOG OF INDUSTRIAL MINERALS LIMITED

SALT WELL NO. 3 AT WATERWAYS

(Incomplete)

Surface elevation, 853 feet above sea level.

| Depth in feet | Description |
|---|---|
| 0-10 | - Clay |
| 10-23 | - Gravel and small boulders |
| 23-42 | - Sand |
| 42-75 | - Bituminous sand |
| 75-151 | - Shale, soft |

Top of Waterways Formation

| | |
|---|---|
| 151 | - Limestone, grey-buff |
| 160 | - Limestone, mottled, buff and grey, stylolitic. |
| 175 | - Shale calcareous green-grey |
| 250 | - Limestone mottled buff and colorless fossil fragments. Colorless is crystalline calcite. |
| 265 | - Limestone argillaceous, buff-grey, fossiliferous.<br>Atrypa devoniana<br>Fish plates |
| 275 | - Limestone, mottled, buff and dark brown |
| 290 | - Limestone, buff and<br>Fish plates<br>Stropheodonta navalis Swallow<br>Crinoid stems |
| 300 | - Limestone buff, calcite veins |

Stropheodonta callowayensis Swallow

310 - Shale, calcareous, green-grey

330 - Limestone, mottled buff and green-gray, and green-grey shale interbands.
Atrypa devoniana Webster
Stropheodonta sp.

340 - Shale, calcareous, green-grey
Trochiliscids
Crinoid stems

370 - Shale, calcareous, green-grey
Atrypa devoniana Webster

390 - Shale, calcareous, green-grey
Atrypa devoniana Webster
Spirorbis omphaloides Goldfuss
Leptodesma sp.

420 - Limestone argillaceous, buff-grey, and green-grey calcareous shale interbands.

450 - Shale calcareous, green-grey
Atrypa devoniana Webster
Cyrtina billingsi Meek

460 - Shale, calcareous, green-grey very fossiliferous band.
Cyrtina billingsi Meek
Atrypa devoniana Webster

470 - Shale, calcareous, green-grey
Atrypa cf. gregeri Branson
Leptodesma sp.
Lingula cf. ligea Hall

480 - Limestone, argillaceous, buff-grey,
Atrypa albertensis Warren
Athyris sp.
Modiomorpha sp.

490 - Shale, calcareous, green-grey
Lingula cf. ligea Hall
Tentaculites mackenziensis Kindle

496 - Shale, calcareous, green-grey
Tentaculites mackenziensis Kindle

510 - Shale, calcareous, green-grey
Leptedesma sp.
Tentaculites mackenziensis Kindle

510 - Limestone, buff-brown, dirty, crystalline, fossiliferous
Atrypa albertensis Warren
Nautiloids
Gastropod - Diaphorostoma type

515 - Waterways - Middle Silurian (?) Contact

520 - Limestone, crystalline, colorless, and buff dolomite, fine with interbands

525 - Middle Silurian (?) - Pre-Middle Silurian Contact

525 - Anhydrite, finely crystalline, buff-grey, dolomitic

530 - Rock gypsum, brown, crystalline, some dolomite and anhydrite interbands

535 - Anhydrite, finely crystalline, grey-buff, with brown gypsum inclusions

540 - Anhydrite, mottled, crystalline, colorless, and salty, grey, dolomite

550 - Dolomite, buff with anhydrite veins

556-558 - Dolomite, grey, salty, pink gypsum veins and interbands throughout.

560-570 - Dolomite, salty, green-grey and maroon, splotched

575 - Dolomite, dirty brown

580 - Dolomite, salty, grey-green and maroon splotched

585 - Anhydrite, colorless, crystalline, and buff dolomite intermixed; anhydrite veins cutting through dolomite and anhydrite.

589 - Dolomite, grey and maroon splotched,

veined and banded with anhydrite. Some satin spar interbands cut by anhydrite veins.

616 - Anhydrite, crystalline, lensed with grey salty dolomite

626 - Anhydrite finely crystalline, colorless and buff mottled, dolomitic

635 - Dolomite, buff, lensed with crystalline anhydrite

640 - Anhydrite crystalline, banded with grey, salty, dolomite.

649 - Dolomite, buff, some anhydrite

650 - Anhydrite, crystalline, buff-brown, dolomitic

655 - Anhydrite, crystalline, and grey, salty, dolomite lenses

660 - Anhydrite, finely crystalline, buff brown, and dolomitic.

680 - Dolomite, buff

690 - Anhydrite, crystalline, and grey-brown dolomite lenses

695 - Anhydrite, crystalline, grey brown, dolomitic

700 - Dolomite, buff

714 - Dolomite, buff, with thin salt band

715 - Dolomite, buff, some anhydrite bands

723 - Anhydrite, finely crystalline, blue-grey and buff mottled, dolomitic.

723-934 - Rock salt, both upper and lower contacts are irregular

934 - Anhydrite, crystalline, mottled, colorless and buff, with salty dolomite

938 - Upper Ordovician - Pre-Middle Silurian Contact

938 - Limestone, dolomitic, buff to brown, and black bituminous, porous, vuggy, dwarf fauna
Gastropods
Ostrocods

942 - Limestone, buff-brown, mottled with darker brown, porous, fossiliferous dwarf fauna
Brackio pod - Rhynchotrema capax type
Gastropod - Hormotoma gracilis, Hall ?
Ostracods - Aparchites whiteavesi Jones ?

952 - Limestone, dolomitic, black bituminous finely bedded, fossiliferous
Tentaculites sp.

Bottom of Well

## IV The Precambrian

In the Alberta Government Salt Well No. 2, which is located near the junction of Deep Creek and the Clearwater River, Precambrian grey granite was struck at 785 feet, and was penetrated to a depth of 4 feet. The total depth of the well is 789 feet.

Overlaying this granite is a 4-foot zone of breccia. The makeup of this breccia is a s follows:

Breccia pebbles - quartz, feldspar and anhydrite.

Matrix - dolomite and some gypsum.

Minor grains - pyrite, garnet and biotite.

Precambrian (?) rocks have been reported in place within a triangle formed by the Muskeg River and the Athabaska River in Twp. 94, R. 10, W. of 4th Meridian.(28)

Other knobs of Precambrian appear in Twp. 100 and Ranges 4 and 5, and in the junction between the two branches of Reed Creek. On Marguerite River, Twp. 101, R. 4 and 5, outliers of the main Precambrian are present. Pleistocene and Recent deposits cover most of the Precambrian in the area to the east and southeast.

## V The Upper Ordovician (Richmond)

### 1. Industrial Minerals Ltd. Well No. 3. (Map 2)

Fourteen feet from the bottom of the Industrial Minerals Ltd., No. 3, at 938 to 952 feet a lithological change occurs. These sediments are buff-brown to dark brown mottled limestone and dolomite limestones. Porosity seems mainly due to fossil cavities. Black bituminous limestone interbeds are present and the one at 952 feet contains Tentaculites quite unlike Tentaculites mackenziensis Kindle of the Waterways formation.

An examination of the limestones and dolomitic limestones reveals a dwarf fauna as follows:

Brachiopod - Rhynchotrema (?) nearest capax type

Gastropods - Hormotoma gracilis Hall ?

Ectomaria pagoda (Salter)?

Loxonema murrayanum Salter?

Ostracod - Aparchites whiteavesi Jones

This fauna is probably Richmond in age (Upper Ordovician).

2. Industrial Minerals Ltd. Well No. 1 (Log in back pocket)

In the Cottee No. 1 well at Waterways, a lithological change occurs at 897 feet. This is one foot above the bottom of the well. This limestone is identical with that of No. 3, Well at Waterways which has just been described. Therefore, it also is considered upper Ordovician in age.

3. Further Evidence to Support Richmond Age

(1) Verbata No. 2, Unity, Saskatchewan

Both a Richmond fauna and a lithology similar to that at Waterways was found at Verbata Well No. 2. (L.S. 7, Sec. 24, Tp. 41, R. 24, W. 3 Mer.)

(3) Vermilion Consolidated Oils Ltd. No. 15, Vermilion, Alberta, L.S.D. 6, Sec. 12, Tp. 49, R. 6, W. of 4.

A series of buff-brown porous limestones and dolomites below the salt are considered Cambro-Ordovician in age. (92)

(4) Red River Formation, Southern Manitoba

Lithologically the beds of upper Ordovician exposed in the Lake Winnipeg area (61) are similar to those at Waterways. The Stony Mountain in particular is described as grey to yellowish, subcrystalline limestone, with layers and mottled areas of yellowish brown dolomite.

The same fauna is found in the Stony Mountain, namely:

Rhynchotrema capax
Hormotoma cf gracilis
Aparchites whiteavesi

(5) The Hudson Bay Region

Savage and Van Tuyl (61) consider the Shammattawa limestone correlative with the Stony Mountain of Manitoba both from the standpoint of lithology and faunal bases. They correlate the fauna of these beds with the upper fauna of the Bighorn dolomite in Wyoming.

(6) The North Arm of Great Slave Lake

Hume (32) and Foerste (29a) have described small collections of fossils of Upper Ordovician age at Red Rock point on the North Arm of Great Slave Lake. Here massive red dolomitic fossiliferous limestone grades to buff dolomitic limestone to the north. At Gypsum Point farther to the south gypsum occurs bedded and veined with the red

(6a) Snare River and Ingray Lake, N.W.T.

Lord(94) describes a Richmond (Upper Ordovician) fauna in dolomite and sandy dolomite overlying the Precambrian 11 miles from the mouth of the La Martre River. The Silurian-Ordovician-Precambrian relationship at Waterways is remarkably similiar to Lord's description at La Martre River.

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(7) Lake Nicholson, N.W.T.

This lake is located about 200 miles east of Great Slave Lake and just to the south of Lake Dubawnt. Tyrrell (1897, p. 54f)(52) collected Upper Ordovician fossils that correlate with the Bighorn fauna.

(8) Alaska and Yukon

Upper Ordovician fauna has been found Seward Peninsula, White Mountains, Porcupine and Yukon Rivers (52)

(9) McKenzie Mountains

Upper Ordovician is also believed to be present in the McKenzie Mountains (85).

(10) Tigonankweine Range

Keele (52) found a few fossils of Upper Ordovician age in the Tigonankweine Range which is west-central from the McKenzie Mountains, N. W. T.

(11) Beaverfoot-Brisco Range of Southeast British Columbia.

Walker's (75) Beaverfoot Formation contains an Upper Ordovician fauna which correlates with the Bighorn of Wyoming. A fauna, Beaverfoot in age, is also present in Kananaskis, Palliser map area, Alberta (90).

(12) Commonwealth Milk River Well, Northeast of Milk River, Alberta

The ostracod Aparchites is found below the Devonian in sediments lithologically similar to the Bighorn limestone (93).

(13) Sunset Pass, near Mt. Coleman, Alberta

In a canyon on the west side of Sunset Pass near Mt.

Coleman gastropods and orthoceras were found by Allan (6)

Conclusion

The evidence presented indicates the possibility of Upper Ordovician at the base of Industrial Minerals Limited No. 3 Salt Well at Waterways, Alberta. Lithology, fauna, and the apparent widespread nature of the Richmond Sea strongly indicate Upper Ordovician. The westward trend of Upper Ordovician north of Lake Winnipeg, its presence at Unity and Provost, as well as the north south trend of the Ordovician on the North Arm of Great Slave Lake suggests that the Richmond seaway passed Waterways, Alberta.

## VI Pre-Middle Silurian or Middle Silurian ?

### 1. Definition

These beds may be defined as the dolomite, dolomitic anhydrite, salt and gypsum beds that overlie the porous buff to buff-brown mottled limestone and dolomitic limestone of the Upper Ordovician age. The upper limit is the brown crystalline rock gypsum and powdery white gypsum. Overlying the gypsum anhydrite dolomite salt are thin-bedded, platy, creamy to dark brown, fractured, and calcite veined limestone and dolomitic limestone of Middle Silurian age.

Whether this gypsum-anhydrite-dolomite-salt series is Upper Ordovician, Lower Silurian, or Middle Silurian in age is unknown. Consequently it is assigned Pre-Middle Silurian or Middle Silurian in age. The writer is inclined to believe that the evidence indicates either Upper Ordovician or Lower Silurian or both.

2. Local Relationships of the Pre-Middle Silurian or Middle Silurian (?) in the McMurray Area

In the Alberta Government No. 2 this series overlies a 4-foot breccia zone of granite pebbles, quartz and anhydrite in a matrix of dolomite and some gypsum. Underlying this zone is the Precambrian grey granite.

In the Industrial Minerals Ltd. No. 1 and No. 3 the Pre-Middle Silurian series overlies upper Ordovician.

The Alberta Government No. 1 does not penetrate ~~through~~ the anhydrite-dolomite salt-gypsum series.

In each case this series is overlain by Middle Silurian.

3. Sub-division of the Pre-Middle Silurian or Middle Silurian ?

The following correlation table shows the subdivision as it applies to the three wells logged by the writer:

| Description | A.G.No.1 | I.M.L.no.1 | I.M.L. 3 |
|---|---|---|---|
| Rock Gypsum | 2' | 3' | 5' |
| Dolomitic anhydrite and dolomite | 70' | 33' | 25' |
| Dolomitic red beds | 10' | 40' | 56' |
| Dolomitic anhydrite and dolomite | 63' | 124' | 107' |
| Rock salt | 14' | | |
| Dolomitic anhydrite and Dolomite | 23' | | |
| Rock salt | - | 199' | 211' |
| Dolomitic anhydrite | - | 4' | 4' |

A.G. No. 1 = Alberta Government No. 1 Well.
I.M.L. = Industrial Minerals Limited.

4. Distribution of the Pre-Middle Silurian or Middle Silurian (?) Series

This series of dolomite, dolomitic anhydrite, salt, and gypsum is widespread, both to the north of Waterways and to the south and southeast into Manitoba. The following occurrences are evidences of this:

(1) Fort McKay Well (3)

This well, located on the west bank of the Athabaska River, 1 mile north of Fort McKay, penetrated no rock salt, but struck a strong flow of salt brine.

(2) Athabaska Oils Ltd. (3)

In 1912 this company drilled a well which penetrated through limestone into gypsum salt and limestone. This well is located 20 miles below Fort McKay.

(3) McMurray Area

Sproule (67) estimated that there are about 300 feet of dolomite limestones, salt and gypsum present in this region of Silurian age. His evidence was based on a poorly preserved fauna, which he thought was Silurian in age. Recently a collection of fossils from along the Clearwater River, east of McMurray has been determined as Guelph in age (93). The upper limestones are, therefore, Middle Silurian in age.

(4) La Saline

Allan (3) reports strong saline springs 27 miles north of McMurray on the east side of the Athabaska River valley at La Saline. Allan believes the source of this salt to be the same as that of at Salt River in northern

most Alberta. This places the source in beds called "Fitzgerald dolomite" by Cameron (15). There are not Upper Silurian in age but Middle Silurian and older.

(5) The Salt River Escarpment

This escarpment is west of Fort Smith, Alberta. This plain rises five to six hundred feet above a salt plain through which Salt River meanders on its way to the Slave River. Allan (3) states that this escarpment consists largely of anhydrite, gypsum, and dolomitic limestone. Salt springs arise from the base of this escarpment.

(6) Peace Point on Peace River, Alberta

Cameron (15) and later Kindle (41) described the Fitzgerald dolomite at Peace Point. Anhydrite and gypsum were overlain by thin-bedded limestones and dolomitic limestones. Kindle (41) found Spirifer crispus in this upper bed, and the age was, therefore, Middle Silurian.

This section is correlated with the Salt River Escarpment by Allan (3). The writer has correlated a thin Middle Silurian section as well as the Pre-Middle Silurian or Middle Silurian (?) from the salt wells at Waterways with this Fitzgerald dolomite at Peace Point.

The basis for this correlation was lithological. The recent discovery of a Guelph fauna on the Clearwater River (93) has confirmed that correlation. Camsell (18) described anhydrite changing to gypsum at Peace Point. The writer found this to be true in the gypsum zone of the salt wells at Waterways and McMurray.

(7) Slave River Outcrops

Camsell (18) and Cameron (15) described 10 feet of thin bedded impure gypsum overlain by 20 feet of fractured brecciated limestone at LaButte on Slave River.

(8) Imperial Oil Co. Well, Nintsi Point (15)

In this well, on the north shore of Great Slave Lake, the Fitzgerald dolomite consists of 20 feet of brown dolomitic limestone, underlain by 255 feet of anhydrite, gypsum and grey dolomitic limestone with gypsum underlying the Fitzgerald dolomite are the "Red beds". This series is 595 feet thick and consists of red shale, with gypsum and red stained salt and anhydrite.

(9) Gypsum Point, Great Slave Lake

Underlying grey porous fossiliferous limestone containing Pycnostylus guelphensis a Guelph fauna of Middle Silurian age, are red shales and gypsum and a lower

sandstone, at the base of which is not exposed (15). Hume (32) describes red beds of dolomitic limestone capping the sandstone at Red Point. Farther north on the same stratigraphic level Hume finds an Upper Ordovician fauna in red dolomitic limestones.

(10) Wrigley-Cap Mountain Section of Franklin Mountains, N.W.T.

Williams' (87) Franklin Mountain formation of Lower Silurian age is composed of 500 feet of buff dolomite, pea-green shale, and sandy red shale, with Rhipidomella hybrida and R. circulus in the upper 20 feet. This was overlain by the Mt. Kindle formation of Middle Silurian age. No upper Ordovician was found.

(11) Bear Rock Section, Fort Norman

Stelck (35) describes red and green shales and gypsum below thin-bedded limestone and dolomite of Silurian age that correlates with Middle Silurian of other regions nearby. Stelck considers these red and green shales and gypsum Silurian, Ordovician, or older.

(12) Carcajou and Norman Ranges

Hume (31a) places red gypsiferous shales below well bedded limestones of Middle Silurian age as questionably

Ordovician. No fossils were found in these red shales.

(13) Vermilion Ridge Well No. 1, Normal Wells, N.W.T.

Hard, dense, dolomitic limestone of the Ronning Formation (Silurian) is underlain by anhydrite and green shale interbands, and red and green shale with dolomite and gypsum and a 1200-foot salt series which overlies Middle Cambrian (72).

(14) Vermilion, Alberta

In the Vermilion Consolidated Oils, Limited, Well No. 15, L.D.S. 6, Sec. 12, Tp. 49, R. 6, W. of 4 Mer. the dolomite-anhydrite-salt-gypsum series occurs below the Devonian. Salt beds are 415 feet thick. Overlying these are dolomitic red beds. Hume (92) believes this salt is Devonian in age based on Trochiliscids found just below the salt.

(15) Unity Valley Well No. 2, Unity, Saskatchewan

Edmonds (27) reported a thin band of gypsum at 2940 feet. From this depth occasional gypsum seams occur; also threads or veinlets are to be seen penetrating the dolomite. Rock salt was penetrated at 3110 feet. About 800 feet of Devonian lie above the gypsum.

(16) Verbata No. 2 Well, Unity, Saskatchewan

About 900 Feet of dolomite, anhydrite, salt and gypsum lie between probable Middle Devonian (85) and the Upper Ordovician which was determined by the fossil Rhynchotrema capax. About 440 feet of these beds are salt. Overlaying the salt series are dolomitic red beds.

(17) Manitoba Section, Lake Winnipeg Region

Kindle's (36) Stonewall formation consists of:

(3) Hard light grey or drab dolomite limestone (Leperditia hisingeri zone)

(2) Gypsum beds

(1) Buff dolomitic limestones (Conchidium decussatum)

Wallace (77) reports much anhydrite in the lower part of the gypsum zone. There is no proof of the source of the salt springs. Wallace also reports reddish argillaceous limestones in the Upper Mottled Limestone and red shales in the Stony Mountain Formation (Ordovician)

(18) Deep Wells in Manitoba

Johnson (35a) ascribes to Silurian about 470 feet of red shales, pink limestones and pink dolomite in the Commonwealth Petroleum Manitou No. 1. This overlies

Upper Ordovician, determined by microfossils. Gypsum also occurs higher up in the Middle Devonian. Wickenden (86a) assigns to Silurian a series of red shales, red dolomites, anhydrite and gypsum in the Dauphin Well. In the Winnipegoses Well red and pink dolomites overlie Stony Mountain (Ordovician) and are placed in the Silurian. At Mafeking No. 3 Well about 300 feet of dolomites containing some pink and red beds overlie 200 feet of hard dense buff to cream dolomite with Leperditia at the base. Wickenden places these beds in the Silurian. Wickenden also reports red beds and gypsum in the Devonian.

(19) North Dakota

Seager et al. (62) recognizes the probability of the Manitoba section of Silurian extending into northeastern North Dakota. Well samples do not indicate any areal extent of Silurian in North Dakota. In Carter's Northern Pacific No. 1, there are 1,590 feet of Ordovician. It contains the Bighorn fauna, Rhynchotrema cf. capax, Dalmanella cf. meeki and the maroon and green shales in earthy and crystalline dolomites.

Kline's (43) report of the log of a well at Grafton shows red shale beds present in the Red River, and the Stony Mountain (Ordovician). It is present in the Stonewall formation (Silurian) and also in the Devonian.

In the Hamilton Well there is a strong saline flow in the Stonewall - Stony Mountain Series.

The log of the Prairie Oil and Gas Co. of Kidder County shows salt water as being present in the Stonewall-Stony Mountain Series.

Generalizations from the Evidence

1. Sediment were deposited by the Ordovician Sea from the Mackenzie River Basin to the Blackhills of the Dakotas.

2. Red beds are present in the Upper Ordovician in the Norman Wells and at the North Arm of Great Slave Lake. Red beds are also present in Southern Manitoba and North Dakota.

3. Red beds also extend up into the Devonian of Manitoba and North Dakota.

4. Red beds overlie salt from Norman Wells to North Dakota, though these may not always be the same age.

5. Salt water is present in the Stonewall-Stony Mountain series of North Dakota. The source of Salt springs in Manitoba may also be the Stonewall-Stony Mountain series.

6. The Lower Silurian Stonewall formation carrying the Conchidium or Virginia decussata and Leperditia hisingeri fauna and the middle gypsum and anhydrite beds apparently grade to the west to pink and buff dolomite beds with some anhydrite and gypsum.

7. Except in the Northeastern North Dakota this Silurian is not recognized.

8. There is probable Lower Silurian in the Franklin Mountains of N.W.T. with sandy red shale at the base.

9. Middle Silurian limestones and dolomitic limestones overlie dolomitic red beds, red shales, anhydrite gypsum and salt from Norman Wells to Waterways.

10. No evidence of Middle Silurian has been found from Waterways to North Dakota.

11. The trend of the evidence seems to favor a Stony Mountain-Stonewall (Lower Silurian-Upper Ordovician) age for the dolomite, anhydrite, salt and gypsum series.

12. Gypsum seems to be associated with the uppermost beds of the dolomite-anhydrite-salt-gypsum series from Gypsum Point to Unity, Saskatchewan.

12. The lack of strong positive evidence has caused

the writer to define the dolomite-anhydrite-gypsum-salt series at Waterways as Pre-Middle Silurian or Middle Silurian (?) but younger than part of the Upper Ordovician.

## Middle Silurian

### Definition

The Middle Silurian at the Waterways and McMurray salt wells consists of 3-5 feet of thin-bedded, platy, creamy to buff-brown, fractured and calcite veined limestone and dolomitic limestone. Some dark brown plates have bitumin. There are no fossils. The underlying beds consists of powdery to dirty white rock gypsum and crystalline deep brown rock gypsum, dolomite, dolomitic anhydrite and salt of Pre-Middle Silurian or Middle Silurian (?). The overlying beds are the calcareous shale and the limestones of the Upper Devonian period.

### Middle Silurian at McMurray and Waterways

Five feet of Middle Silurian beds are present in the Alberta Government Salt Well No. 1 at McMurray. At Industrial Minerals Limited Salt Well No. 1, Waterways, Alberta, these limestones and dolometic limestones are 3½ feet thick. At the No. 3 well this bed is about 5 feet thick.

Evidence for Middle Silurian Age

The writer proposes the following evidence for support of Middle Silurian age of these beds:

(1) Kindle's Peace Point Section

Kindle's (41) section at the "Upper End of the Cliffs" at Peace Point is as follows:

(a) Thin-bedded, drab, slightly magnesian limestone ..... 10 feet.

(b) White and cream colored anhydrite and gypsum in thin horizontal ribbon-like bands ..... 50 feet.

(c) White gypsum and anhydrite ... 6 feet.

The presence of Spirifer crispus found in the uppermost 10 feet establishes the age as Guelph, or upper Middle Silurian. This 10-foot bed resembles the 3-5 feet of Middle Silurian beds at Waterways and McMurray Salt Wells in lithology. Both at Peace Point and at Waterways these beds overlie rock gypsum and anhydrite.

Two miles below the section at the "Upper End of the Cliffs" Kindle describes:

(a) Lake clay ..... 6 feet.

(b) Glacial clay and boulders ..... 9 feet.

(c) Blue shale and thin-bedded limestone with

abundant Devonian fossils .... 8 feet .... angular unconformity .....

(d) Grey, thin-bedded, bard, argillaceous limestone, with a metallic ring, lower third brecciated ..... 70 feet.

Kindle states that (c) and (d) beds have the sharpest contrast lighologically and faunally.

This section shows the same relationship of the upper Devonian Portage to the Middle Silurian platy limestones and dolomitic limestones as does the Upper Devonian at Waterways to the platy limestones and dolomitic limestones underlying it.

(2) La Butte Section

Camsell (18) measured two sections on the west bank of the Slave River opposite to La Butte. The northernmost section contained: Limestone fractured, broken ... 20 feet; Gypsum, thin bedded, impure .... 10 feet.

The other section was as follows:

Massive limestone fossils ..... 5 feet.
Pebbly limestone ..... 10 feet.
Brecciated limestone bituminous ... 6 feet.
Grey limestone, thin bedded ..... 10 feet.

Fossils from the upper part of this last section were Middle Devonian. Cameron (15) was of the opinion that the lower part was Silurian on the basis of the lithology of the limestone and the underlying gypsum.

(3) Stony Island Section

About 12 miles above Fitzgerald, Alberta, on the Slave River Cameron (15) described the Stony Isl and section:

Limestone, light colored, massive, grading down to dark grey dolomitic limestone ..... 6 feet.

Sandstone, conglomerates, arkose, granite, Coarse grained, porphyritic ..... 8 feet.

(4½" seam of black bituminous shale in the limestone).

Kindle found a Silurian fauna in the limestone of this section.

(4) Gypsum Point

Cameron (15) found Pycnostylus guelphensis at Gypsum Point on Great Slave Lake in thin-bedded, fine-grained, dark grey, badly fractured, soft, dolomitic limestone. These beds were above gypsum. Pycnostylus guelphensis is Upper Middle Silurian in age.

(5) Clearwater River

On the Clearwater River at the Cascade Rapids, Sproule (28) described "massive dolomites and thinly banded arenaceous and argillaceous limestone .... that yield a limited number of poorly preserved gastropods, pelecypods, and brachiopods, are probably Silurian."

Recently a Guelph fauna has been described from beds exposed on the Clearwater River east of McMurray (93).

4. Conclusion

This evidence makes tenable the assignment of a Guelph age to the 3-5 feet of thin-bedded, platy fractured limestones and dolomitic limestones in the Salt Wells of McMurray and Waterways.

## VIII The Upper Devonian

### 1. Definition

The Upper Devonian series of mottled limestones, argillaceous limestones and calcareous shale was termed the Waterways formation by Warren (82). This formation is underlain by Middle Silurian at Waterways and McMurray. It is overlain by recent alluvial sediments from the Athabaska and Clearwater Rivers. Elsewhere the Waterways

formation is capped by the Lower Cretaceous, McMurray sandstone which contains bitumen. Total thickness of the Waterways formation is not known in the McMurray region because the upper part has been eroded off.

2. The Waterways Formation at Waterways and McMurray

A maxiumm thickness of 402 feet of Waterways limestone and calcareous shale was measured in the Alberta Government Well No. 1 at McMurray. The top of the Waterways formation is an erosional surface. Alluvial clays, silts sands, gravels, limestone debris 15 feet thick overlies this surface in the Alberta Government Salt Well No. 1.

In Industrial Minerals Limited No. 1 Well, the Waterways formation is 390 feet thick. Overlying its erosional surface is 100 feet of unconsolidated material.

In the No. 3 Well the Waterways formation is approximately 364 feet. Overlying the top of the Waterways are 151 feet of soft shale, bituminous sand (Lower Cretaceous in age) and then unconsolidated material.

In the Alberta Government No. 2 Well there is about 370 feet of Waterways. This is overlain by 40 feet of unconsolidated materials.

Limestone outcrops at the confluence of the Athabaska

and Clearwater Rivers at McMurray, Alberta. This limestone is part of the Waterways formation. It carries a Portage fauna. This fauna is lowermost Upper Devonian in age.

The main collections of fossils from the limestone outcrops in the McMurray area are those of Dr. J. A. Allan and Dr. K. A. Clark of the University of Alberta (82). Dr. Allan also collected fossils from the core of Cottee No. 1 Well (7) and from Alberta Government Well No. 1(1). These along with collections by the writer are correlated with Portage-Naples faunas from other parts of North America in Table No. 2 which is enclosed in the pocket at the back of this report.

Table No. 1 (in the pocket) represents a correlation of lithology and fauna within the Waterways formation in the three salt wells studied by the writer.

A study of Table No. 2 indicates a strong resemblance between the Waterways and Snyder Creek, Missouri, faunas. Buchiola, Entomis and Manticoceras are yet to be found at Waterways and McMurray.

The trochiliscid oogonia prove an interesting flora. They are present in the Lime Creek formation of Iowa (91)

which correlates with the Snyder Creek formation.

Conodonts which are present in the Waterways formation are described by Youngquist (91) in the Independence shales at Middle Amana, Iowa. Conodonts are described by Baker (9) as present in the Olentangy shale of Ohio. Since Manticoceras is present in the Olentangy shales these conodonts are considered basal upper Devonian in age.

## Chapter V

## Petrology and Petrography

### I General Statement

The intention is to discuss both the common and unusual features of the log of Cottee Well No. 1. In the main it will be petrological but petrography will be brought in to support observations made. Things of special interest in the No. 3 Well and in the Alberta Government Salt Wells Nos. 1 and 2 will be included where they are related to this study.

### II Alberta Government Salt Well No. 2 (785-789 feet)

A specimen was taken from a 4-foot section of core at the bottom of Alberta Government Salt Well No. 2 by Dr. J. A. Allan. A thin section was also made.

#### Hand Specimen Description

Color on fresh surface is grey black; on weathered surface it is brownish grey black. Coarse grained, granitic texture with no apparent sign of alteration. The minerals observed are:

feldspar
quartz
pyrite
biotite

Microscopic description

| | | |
|---|---|---|
| Oligoclase | 60% | |
| Quartz | 30% | |
| Biotite | 4% | |
| Pyrite | 3% | |
| Secondary quartz | 3% | (vein) |
| Chlorite | | |

This rock is classified as granite. It is mineralized with disseminated pyrite.

III Alberta Government Salt Well No. 2
(781-785 feet)

Overlying the Precambrian mineralized granite is a 4-foot zone of breccia. The main constituents are: rock fragments of: oligoclase, quartz, and biotite; quartz pebbles, and anhydrite pebbles or globules; cement - dolomite, with biotite, chlorite and garnet; and veins - satin spar. Overlying this breccia zone is dolomite, dolomitic anhydrite, anhydritic dolomite and salty dolomite. Here clastic sediments from an exposed or continental condition are mixed with non-clastic sediments. Feldspar and quartz fragments show no rounding whatsoever. Consequently, these fragments must have been deposited very near to the source of production. This breccia may be described as arkosic but not as an arkose because the feldspar content is less than 25% of the rock. It isquite probable that the feldspar content is variable and much of the braccia may be classed an arkose.

Further support of shore conditions is the presence of anhydrite and dolomite, of feldspars which have the colors of the composing minerals at the source. Little or no decomposition of these feldspars is observable.

IV Bottom of Industrial Minerals Limited Well No. 3 (952 feet)

The lowermost core sample contained a 2" band of black bituminous limestone. Fine bedding is obvious and a few minute tentaculites with wide annulations occur in the sample examined.

Though the evidence of environmental conditions is not good, the writer suggests a brackish water environment based on the following facts:

(1) In the overlying 14 feet of limestones and mottled dolomitic limestones, a dwarf fauna was found. This contained ostracods which today favor brackish water conditions.

(2) The fine-bedded limestones suggests quiet waters and slow deposition, (lagoonal conditions).

(3) The presence of oil or bitumen suggests a probable in situ origin for the oil.

(4) Tentaculites occurred at the base of the Upper Devonian in similar conditions. The dwarf fauna, however, was earlier since it was found at the very base, while the tentaculites were found a few feet above.

## V No. 3 Well from 938-952 feet

### 1. Mottled Dolomitic Limestone

This 14-foot section consists of porous, fossiliferous, buff and brown, mottled dolomitic limestone. These sediments contain a dwarf fauna upper Ordovician in age. The evidence for this age is the Orthid and Rhynchonellid type brachiopods; the Loxonemia, Hormotomia, Ectomaria, Lophospira type gastropods, and the ostracod Aparchites whiteavesi Jones.

### 2. Observations

An examination of these sediments brings out the following observations:

1. The mottled patches are quite irregular and seem to show no relation to any guiding influence.

2. Fossils are present in both light and dark patches. They do not seem to influence the mottling.

3. The preservation of the fauna is generally poor.

This observation has been expressed by many writers in relation to dolomitic limestone.

4. Internal molds of fossils are often partially or completely lacking a factor which contributes mainly to the porosity of the rock.

5. Geode-like colorless twinned calcite partially fills the cavities of many fossil shells.

6. The fauna is a dwarf fauna with gastropods and ostracods most abundant.

7. One small veinlet contained both satin spar and anhydrite. The anhydrite is partially altered to gypsum.

8. Microcrystalline dolomite is present in aggregate form with the limestone in both the buff and the brown.

9. Ankeritic dolomite is present in both the buff and the brown, but more so in the brown.

10. Some internal molds of gastropods in the brown patches are buff colored.

11. Oil stained bands are present throughout the 14-foot section.

12. These observations apply to the 1-foot section

at the bottom of Cottee No. 1 Well.

## 3. Classification of Dolomitic Limestone

Generally speaking, theories related to origin of dolomitic limestones may be classed as primary or secondary. The classification is expanded somewhat as follows:

(1) Primary deposition of dolomitic limestones

- (a) Deposition as clastics
- (b) Deposition by inorganic chemical processes
- (c) Deposition by organic chemical processes

(2) Secondary deposition of dolomitic limestones.

### (1) Primary Deposition of Dolomitic Limestone

#### (a) Deposition as Clastics

There is no suggestion in Well Core No. 3 of clastic dolomitic limestone deposited, aggregated, and cemented to form a new dolomitic limestone.

#### (b) Deposition by Inorganic Chemical Processes

Wallace (78) brought forward the possibility of magnesium and calcium carbonates being transported as colloids stabilized by protective organic colloids and finally precipitated as an intimate mixture that subsequently crystallizes to form dolomite. Definite proof of this is lacking.

Marine leaching has been advanced as a possibility. Calcium carbonate is more soluble than magnesium carbonate. Thus the magnesium carbonate content would be enriched by leaching of calcium carbonate. The most favorable environment for this is in a shallow restricted lagoon. The solubility of calcium carbonate is also increased by increase in salinity. This is usually true in a lagoonal type of environment. Thick deposits of dolomitic limestone would be accounted for by slow subsidence in the area. Daly's (24) contention that the oceans of early Paleozoic time had a low calcium : magnesium ratio due to lack of source materials would fall in line with this theory of dolomitization by marine leaching.

(c) Deposition by Organic Chemical Processes

Plant and animal structures contain some magnesium carbonate. This quantity may be as great as 25 per cent in some calcareous algae. Whether it forms dolomite or is utilized to form dolomite is not known. Plants also use up carbon dioxide and thereby increases the alkalinity of the sea. This in turn leads to precipitation of magnesium hydroxide. Calcium carbonate precipitates at the same time due to photosynthesis. Magnesium hydroxide probably changes to magnesium carbonate. Porosity may be effected by reduction in alkalinity which may remove

magnesium carbonate from the beds being lithified.

Wallace (76) favors an organic chemical hypothesis for dolomitization and mottling in the Lower and Upper Mottled Limestones of the Ordovician of Manitoba. He considers that the limestone immediately surrounding decomposing algae has been dolomitized, the magnesium salts liberated from the algae being enough to raise the percentage of Mg ions sufficient that recrystallization could take place. This phenomenon would take place with the formation of limestone in the upper layers of calcareous ooze of the sea bottom. In other words it would be practically a contemporaneous process. Furthermore he maintains that a limestone may undergo dolomitization when the percentage of Mg ions in the sea water affecting it is smaller than the chemical equations taken to represent the process would demand. It is likely that the percentage of Mg ions was higher than it is today, yet it was lwo enough so that magnesium salts were not toxic enough to exclude organic life in the seas of that time. Summarily Wallace attributes to fucoids and to unicellular algae of the plackton, the probable main source of magnesium salt sufficient to cause the mottling effect in the Upper and Lower Mottled Limestones of Manitoba.

(2) Secondary Deposition of Dolomitic Limestones

This is the theory of marine dolomitization by replacement of calcium carbonate in the calcareous ooze on the sea floor by magnesium salts contained in the sea water. This theory seems to be the most acceptable one offered to the present time. It fits most of the facts as they are known. The process carries on in sea water at ordinary temperatures in lagoonal areas where saline concentration may be high. Carbon dioxide released from organic decay may disturb the equilibrium of the solution may react with magnesium salts to form magnesium carbonate. How the calcium carbonate and the magnesium carbonate react to form dolomite is not clear. Twenhofel (73) suggests that mottling due to dolomitization is initiated from centres composed of organic or perhaps inorganic materials and forms patches outward from those centres.

4. Application of Theories to No. 3 Well

Many of the postulations set up for secondary deposition of dolomitic limestones satisfactorily answer the observations as established by the writer in Well No. 3. It is conceivable that the area in this region was a shallow sea area. Dolomite may have formed in sheltered lagoons for Precambrian was encountered less than $3\frac{3}{4}$ miles to the east. Whether this was a knob or the true Precambrian shield is not known. Among other possibilities,

the dwarf fauna may suggest a fairly high degree of salinity. Ostracods of today favor brackish conditions and these may have done so in the past. Oil stains could also suggest quiet lagoonal environment.

An interesting feature of this mottled dolomitic limestone is the porosity without apparent permeability. Neither bitumen anhydrite or gypsum fills the cavities. The porous condition is found even within two inches of dolomitic anhydrite.

5. Factors of Doubt

1. Organic material as far as could be observed showed no relation to the mottling, except that internal molds were buff in the dark brown patches.

2. No centres of origin, organic or inorganic, from which the outward processes of dolomitization could be determined, were observed.

3. Dolomite seemed quite dispersed and the dark patches seem to bear some relation to the amount of ferrous carbonate present.

6. Conclusion

The facts are insufficient to support either a primary

or secondary theory of deposition of dolomitic limestone.

VI Cottee No. 1 Well, Pre-Middle Silurian or Middle Silurian Section

This section of the core consists of 4 feet of dolomitic anhydrite; 199 feet of rock salt; 197 feet of anhydritic dolomite, dolomitic anhydrite, salty grey dolomite, buff dolomite, maroon splotched dolomite; some dolomitic limestone; and 3 feet of rock gypsum.

1. Environmental Conditions

These deposits were formed in a lagoonal environment along the eastern margin of a sea similar but more drastic than that of Ordovician time. Desert conditions are conceived and evaporation, concentration, temperature changes, and fresh supplies of water were factors in the precipitation of dolomitic anhydrite, rock salt, dolomite, and dolomitic limestone. As far as the writer is aware there is no evidence to support the deposition of primary gypsum.

2. The Concept of Deposition of Saline Residues

Clark ( 21 ) states that saline constituents deposit in reverse order of their solubility when natural water is evaporated. In general the order of precipitation is

as follows:

1. ferric oxide
2. calcium carbonate
3. magnesium carbonate
4. gypsum and anhydrite
5. sodium sulphate
6. sodium carbonate
7. sodium chloride
8. magnesium sulphate
9. bitterns

But sea water has complicating factors. Solubility is affected by the presence of other compounds, by concentration of the solution, and by temperature. The more complex the constituents of the sea water is, the greater are the possibilities of complex compounds precipitating out. True also is the fact that if all the calcium is used up to form a carbonate no other calcium salts can be formed. Similarly if all the sulphate ions are used to form gypsum then other sulphates cannot form.

### 3. Observations Regarding Saline Deposits in Cottee No. 1 Well

The writer makes the following observations:

#### (1) Microcyrstalline Dolomite

Microcrystalline dolomite occurs throughout the colorless crystalline anhydrite in patches giving it the colorless and buff mottled effect. Where the anhydrite is finely crystalline (626-657 feet, log of Cottee No. 1) not only is the dolomite present in buff patches but

apparently it is disseminated throughout the anhydrite to give it a bluish appearance. Where the anhydrite is coarsely crystalline and often irregularly ribboned, buff microcrystalline aggregated dolomite fills in every interstice. Much of this dolomite is grey to green-grey and salty. It seems probable that the salt is responsible for the dolomite being grey-green instead of the usual buff. Where anhydrite is abundant salt with the dolomite seems scarce or absent.

(2) Rock Salt

The rock salt contacts were irregular but sharp in Cottee No. 1. Dolomitic anhydrite exists above and below the rock salt section. In the No. 3 Well the same set of conditions is present. In the Alberta Government No. 1 Well the upper contact is with salty green-grey dolomite. The dolomite shows penetrative effect of the salt. No complete examination of the 199 feet of salt was made, but optical methods revealed that the rock salt contained cubic and rectilinear air spaces.

(3) Dolomitic Red Beds

From 575 to 530 feet, dolomitic red beds occur at intervals in Cottee No. 1 Well. The presence of iron was established by the use of potassium ferrocyanide. Some

of these red beds are red stained throughout while others are splotched red or maroon and green-grey. Optical examination revealed microcrystalline dolomite but pinkish orange or brownish in color. Whether the dolomite was stained by iron oxide or whether it is an iron carbonate could not be determined on account of microcrystalline size of the dolomite. Tests to remove iron oxide stain were unsuccessful. On the other hand some satin spar veins that pass through these red beds were pinkish. This may suggest iron oxide staining.

Of interest is the occurrence of one dolomitic limestone, maroon colored bed at 571-575 feet. It is also the basal red bed in this well.

(4) Satin Spar Veining

Throughout the anhydrite-dolomite-gypsum series satin spar veining and satin spar banding parallel to the bedding occurs. The association of satin spar veins and bands along bedding is with dolomite. The occurrence of satin spar with dolomitic anhydrite is apparently rare. In many cases a fine dolomitic layer exists between satin spar bands and the purer anhydrite beds. Satin spar veins and interbands are much more common in the salty grey dolomite and in the red beds than in buff dolomite and

dolomitic anhydrite beds. This satin spar veining is secondary in its origin.

(5) Anhydrite Veining

Anhydrite veining occurs in the Cottee No. 1 Well between 513-518 feet. It also occurs in the No. 3 Well at 585 feet and at 589 feet. At 585 feet these anhydrite veins cut through dolomite and an irregular blob of anhydrite. At 589 feet anhydrite veins cut through maroon and grey splotched dolomite and satin spar veins. The anhydrite veining is, therefore, of secondary origin, and post satin spar veining, as well as post dolomite and anhydrite deposition.

(6) Brown Selenite Replacements

Brown selenite replacements occur in the creamy to buff limestone bed at 492-493½ feet. This lies immediately above the rock gypsum contact in the Cottee No. 1 Well. These brown selenite platy crystals occur in the finely crystalline dolomitic anhydrite below the rock gypsum. That is, these crystals are present in the upper part of the section 497-506 feet. This same phenomenon occurs in the No. 3 Well at 535 feet in finely crystalline grey buff anhydrite which is also dolomitic. The origin of this selenite is secondary.

(7) Rock Gypsum

Rock gypsum occurs between 493½-497 feet in the Cottee No. 1 Well. The same zone is present in the other two wells examined. It is a dark brown crystalline rock. Some dolomite is scattered throughout. An optical examination showed some of the gypsum to contain anhydrite inclusions. In other words, the anhydrite was altering to gypsum and consequently the gypsum is of secondary origin.

(8) Limestone and Dolomitic Limestone

Only three occurrences of dolomitic limestone and limestone are present in the Cottee No. 1 Well. These are at the following depths:

620 - 622 feet (dolomitic limestone)
571 - 575 feet (reddish dolomitic limestone)
506 - 507 feet (limestone)

Only one limestone band is present in Alberta Government No. 1 Well. This is at 514-516 feet. It is probable that the 514-516 foot bed correlates with the 506-507 foot band at Cottee No. 1 Well.

4. Conclusions

From the above observations the writer draws the following conclusions:

1. The environment was one of shallow seas, lagoonal embayments, low shoreline, with a paucity of clastic sediments from emergent areas nearby.

2. The source of the ferric oxide is in doubt since it is not known whether the red beds are due to iron oxide staining or to an iron carbonate microcrystalline agglomerate. No clastics bearing iron are present in the dolomite. Hence the probability of desert conditions is unlikely. A moderately wet climate in lowland regions favors the production of ferric oxide, yet the salinity of the seas was high for the red beds are salty, anhydritic and non-fossiliferous.

3. According to Clark's ( 21) concept of deposition of saline residues ferric oxide should be the first to precipitate. This is not the case in the McMurray area. Dolomitic anhydrite and salt precipitate first. The full facts are not known however. Wells drilled to the west of McMurray might prove to have red beds under the salt. On the other hand no red beds are reported below the salt at Vermilion, Alberta, and Unity, Saskatchewan.

4. The maroon dolomitic limestone band between 571-575 feet would seem to conform to Clark's concept of saline deposition.

5. The remarkable amount of dolomite compared with the small amount of limestone is not understood. Practically all the anhydrite contains dolomite but no limestone. More facts are necessary before the theory of marine dolomitization by replacement of calcium carbonate in the calcareous ooze on the sea floor by magnesium salts can be accepted.

6. Much of the anhydrite and dolomite seem to be intermixed, though clear cut bands of dolomite occur. The anhydrite is apparently not free from dolomite.

7. Secondary anhydrite does occur.

8. All gypsum determined by the writer in the salt wells of the McMurray area is of secondary origin. Rock gypsum occurs only in the uppermost bed, or beds of the anhydrite-dolomite-salt-gypsum series.

## VII Middle Silurian in Cottee No. 1 Well

These are the limestone and dolomitic limestone beds between 490-493½ feet. These beds are lithologically different from the underlying series and from the Waterways formation which overlies it. Color, thin platy bedding, fracturing, and calcite veining differentiates it from them. Fracturing and calcite veining is more in evidence in the No. 3 Well and in the Alberta

Government No. 1 Well. Color ranges from a distinct creamy color to dark brown bituminous stained color. All veining examined contained twinned calcite. The remarkable factor is the lack of gypsum or anhydrite veins in these sedmiants.

It was these unusual features that first lead to their isolation from both the Waterways and the anhydrite-dolomite-salt-gypsum series. A survey of the literature lead to the tentative assignment of a Guelph (Middle Silurian) age on the basis of lithology. The discovery of a Guelph fauna on the Clearwater River east of McMurray has led the writer to place these beds in the Middle Silurian.

1. Environmental Conditions

One possible environment is that of an erosional surface slowly subsiding and being covered by fine sediments of a transgressing sea. An exposed surface would account for the formation of secondary gypsum Paleogeographic evidence suggests that this Middle Silurian Sea came down from the north and its known southern limit is Waterways.

VIII The Waterways Formation in Cottee Well No. 1

1. The Lower Limestone (485-490 feet)

This limestone is buff-brown colored and speckled with jet black scolecodonts or worm jaws. A dwarf fauna is also present. Whether it is a youthful fauna or one dwarf due to a restrictive environment is not known. A fauna consisting of scolecodonts, nautiloids and gastropods is indicative of shallow seas. Scolecodonts, generally called conodonts, are usually found at the tops and bottoms of beds. These are the basal beds of the Waterways. Conodonts are also found at 157-160 feet. This is near the base of a limy series which overlies a thick bed of green grey calcareous shale.

2. Calcareous Shale

Characteristic of the Waterways formation is the green-grey calcareous shale. The main beds are indicated on Table 1 (pocket). The high calcareous content is indicative of a more epicontinental environment. The green color is probably due to ferrous iron compounds. No glanconite was found, hence the green cannot be attributed to it.

The lower calcareous shale zones are fossiliferous. Lingulas, Tentaculites, Leptodesmas, and fish plates are abundant. The upper calcareous shale zone is practically barren, (Table 1).

3. Mottled Limestone and Argillaceous Limestone

Generalized zones of mottled and argillaceous limestone are shown in Table 1. The argillaceous limestone contains a greater amount of lime than the calcareous shale.

Mottled limestone is due to several factors. Some of these rocks appear as buff limestone patches in green-grey calcareous shale. Mottling also occurs when buff calcite veinleted lithographic-like limestone appear as patches or blobs in argillaceous limestone. Fossiliferous limestone gives a mottled appearance. This is probably due to organic decay. Brown crystalline limestone is mottled due to colorless calcite replacement centres. The matrix is buff limestone.

4. Stylolites

Much of the mottled limestone is stylolitic. These are mostly in the form of vertically striated pyramids or cones of various heights, widths and shapes. At the apixes of these stylolites, thin deposits occur. These were generally along fractures plains. These stylolites have been formed subsequent to deposition of the limestone. This is indicated by the formation of thin

deposits along fractures and at the apices of the stylolites. The phenomenon seems to be one of solution and pressure. Soluble materials are removed by solution. This would leave a series of pressure points. Readjustments in bedding would occur and consequently cause vertically striated, conically shaped structures. Insoluble material in the soluble parts would escape and form the thin bedded deposits along fractures at the apices of the stylolites.

5. Marcasite

Marcasite is found throughout the Waterways formation in Cottee No. 1 Well. It occurs as fossil replacements; as veins in the calcareous shale; as disseminated grains along stylolitic striations; as the outer coating of nodules; and lastly, disseminated throughout the calcareous shale in fine grains, twinned aggregates, and as arrowhead twins at various horizons.

As far as could be determined no pyrite is present. It all seems to be marcasite.

The time of origin is subsequent in the case of the replaced fossils. It is also subsequent where it is found disseminated along stylolitic striae. Veined marcasite is also subsequent. Marcasite coated nodules

are present in the same calcareous shale zone as dark green shale coated nodules. It is probable that the green shale coating has been replaced by marcasite and is thus a subsequent process. No evidence was found to determine the origin of the disseminated grains, twins, and aggregates of marcasite in the calcareous shale. In all likelihood it also is subsequent to the deposition of the shale. A 6-inch core from Industrial Minerals Limited (1938) in the Mineral Museum of the University of Alberta was examined by the writer to determine whether the abundant iron sulphide was pryrite or marcasite. The crystalline structures observed were characteristically marcasitic. Tabular crystals; radiating fibrous structures; spearhead twinning; arrowhead twinning were observed. On a fresh surface the color was somewhat silverish. The writer concludes that no pyrite is present in the logs of the salt wells observed.

6. Nodules

Nodules up to 1½ inches in length and ¾ of an inch in thickness occur in the Cottee No. 1 Well at the following depths:

484 feet
460 feet
452 feet

The nodules at 484 feet have a twinned marcasite coating

about a limestone interior. A nodule at 460 feet has a somewhat greener calcareous shale coat, but no marcasite. Those at 452 feet were coated with green calcareous shale. In every case the interior of the nodule consisted of limestone with some marcasite grains. Those at 484 and 460 feet were discoidal and ellipsiodal. That at 452 feet was bladed and irregular. These structures were nodular in that they have no internal design. Rather, the design is external. The nodule at 460 feet was abundantly covered with Tentaculites. Most of these were in a good state of preservation. This suggests that the nodules were interformational, that is, they lie along the bedding planes and other sediments were laid down about them. The origin was therefore contemporaneous.

7. Calcite Veining

Calcite veining was observed between 130-140 feet in Cottee No. 1. This calcite had a somewhat sugary appearance. The limestone vein and veinlet walls suggested no replacement of the limestone. Optical examination revealed twin lamellae on the calcite grains. These features suggest cold water calcite deposition and hence may be classed as epithermal.

8. Charophyte Oogonia (Trochiliscids)

Trochiliscids occur from 294-304 feet in the Cottee No. 1 Well in mottled limestone. These occur at two horizons in the Alberta Government Well No. 1, namely,

292 - 296 feet (calcareous shale)
170 feet (calcareous shale)

In the No. 3 Well, Trochiliscids occur at 340 feet in calcareous green-grey shale. Probably the 294-304, 292-296, and the 340-foot horizons correlate, (see Table 1).

According to Peck (55) these fossil oogonia are abundant in the Upper Devonian and Middle Devonian of North America. They occur in calcareous shales and in fresh water limestones or near fresh water limestones. The environmental picture at Waterways would probably be one in which these oogonia developed in a fresh water region such as at a river mouth and later have been rafted out into the limy sea by tide, current, or wave action.

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To accompany Thesis- W.D. MacDonald, 1947.

( after J.A. Allan - Geological Map of Alberta)

Upper Cretaceous

Asphalt Creek

Athabaska Oils Ltd (1105')

Tar River

Bitumont

Muskeg River

Marguerite River

Firebag River

Reid Cr.

100

99

98

97

96

95

94

93

92

91

90

Namur River

Salt of the Earth Well

Muskeg

Fort McKay

Holes Nos 7-11

Dover River

Well No. 5

Well No. 6

La Saline

15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

McKay River

HILLS

THICKWOOD

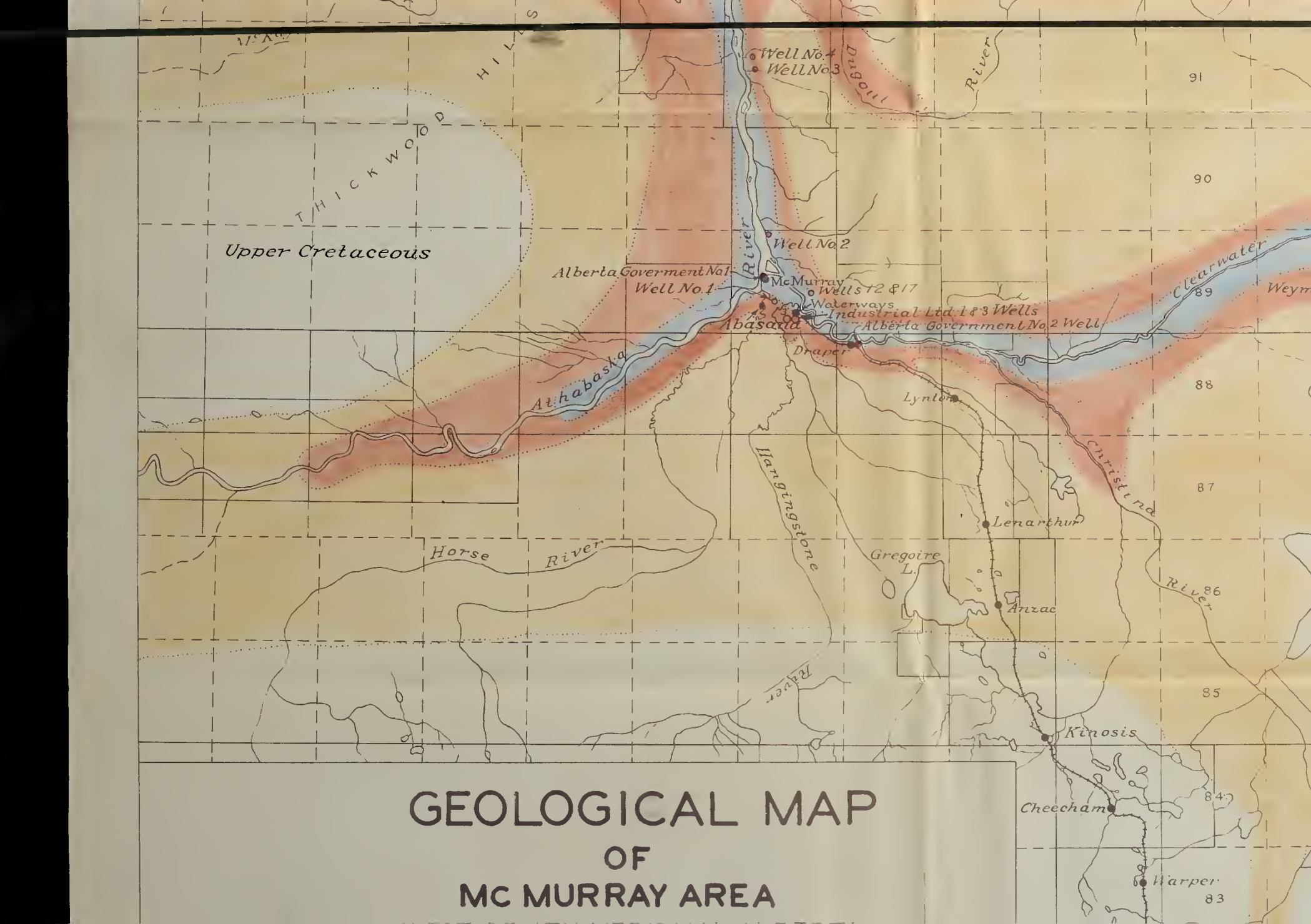
Well No 4

Well No 3

Digby

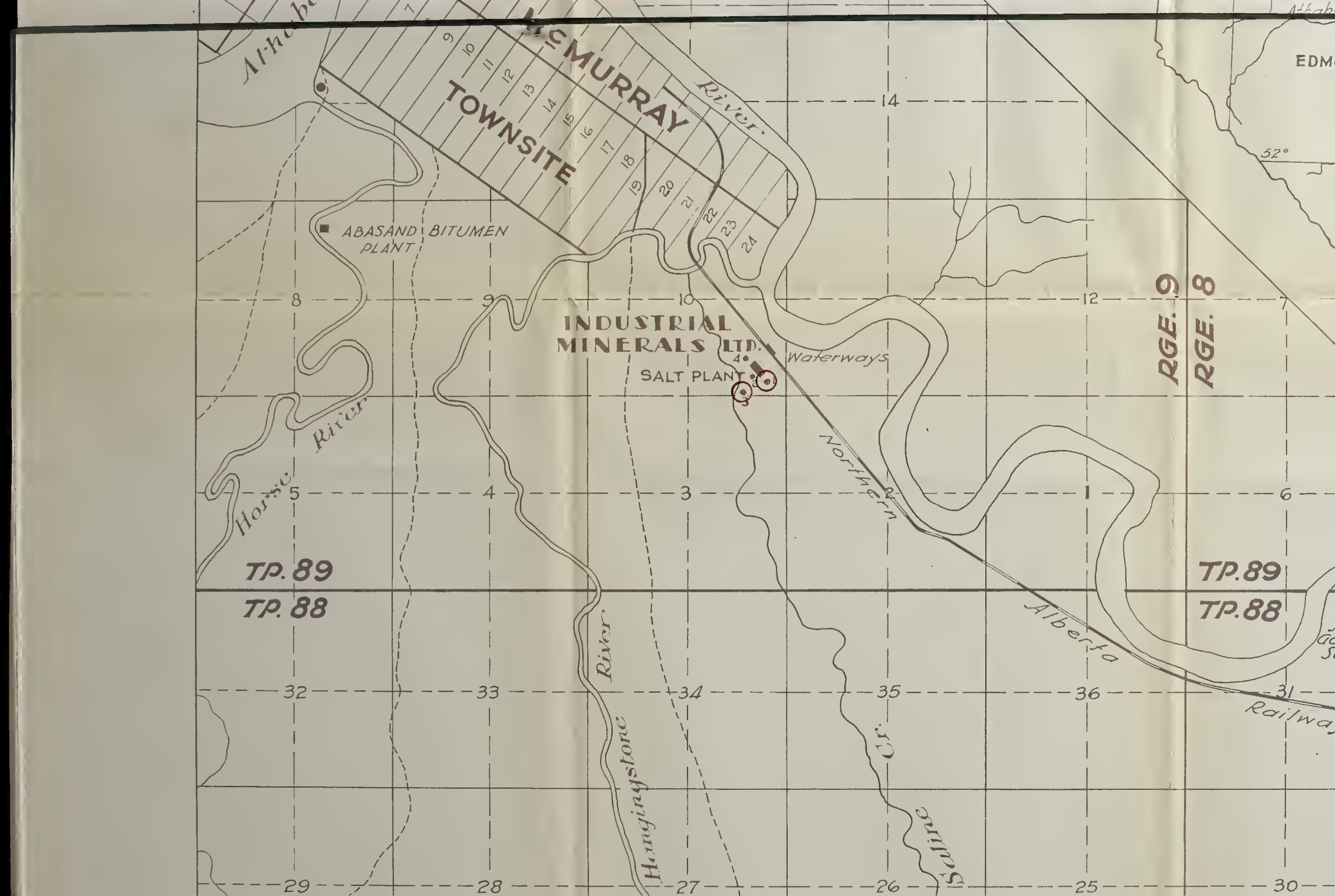
River

FOURTH MERIDIAN ALBERTA - SASKATCHEWAN




# GEOLOGICAL MAP
## OF
## MC MURRAY AREA

To accompany Thesis- W.D. MacDonald, 1947.


McMURRAY
TOWNSITE
River
ABASAND BITUMEN PLANT
INDUSTRIAL MINERALS LTD.
SALT PLANT
Waterways
Horse River
Northern Alberta Railway
Hangingstone River
Cr.
Saline
RGE. 9
RGE. 8
TP. 89
TP. 88
52°
EDM

To accompany Thesis-W.D. MacDonald, 1947.

# SALT WELL NO. 1

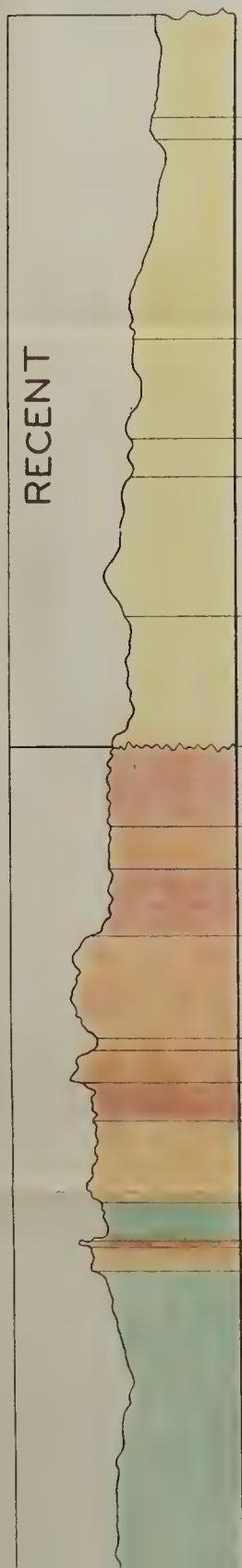
DRILLED BY

ALBERTA GOVERNMENT

LOT 8, FORT Mc MURRAY

SEC. 21, TP. 89, R. 9, W. 4.

SCALE 1 INCH TO 20 FEET. SURFACE ELEVATION 795 FEET.




| | |
|---|---|
| 12 | Loose dirt |
| 16 | Quick sand |
| | Alluvial mud, blue |
| 42 | |
| | Sand, white silica |
| 55 | |
| 60 | Sand and boulders |
| | Limestone, argillaceous |
| 78 | |
| | Crevice sand and boulders |
| 95 | |
| | Limestone, lithographic, fossils, marcasite (Spirifer allani, Atrypa devoniana, crinoid stem) |
| 105 | |
| | Limestone, argillaceous, brown-grey |
| 110 | |
| | Limestone, grey-brown |
| 120 | |
| | Limestone, mottled, marcasite (Spirifer allani) |
| 133 | |
| | Limestone, argillaceous, grey-brown |
| 139 | Limestone, mottled, buff and grey-brown |
| 144 | Limestone and argillaceous limestone |
| | Limestone, argillaceous, grey-brown |
| 155 | |
| 160 | Shale, calcareous, green-grey |
| | Limestone, mottled, fossils (Atrypa reticularis) |
| 164 | Limestone, argillaceous, marcasite (Spirifer allani, Trochiliscus) |
| | Shale, calcareous, green-grey, fragmental |

UPPER DEVONIAN

Shale, calcareous, green-grey, fragmental

Marcasite

223

Limestone, grey-buff, fossils

230

Limestone, argillaceous, fossils

239 Limestone, mottled

Shale, calcareous, green-grey, fossils
(Atrypa devoniana, Schizophoria cf. iowensis)

Limestone, mottled, fossils
(Stropheodonta demissa)

260

Limestone, buff, fossils
(Leda?)

270

(Schizophoria cf. iowensis, Crania, Stropheodonta demissa, Fish plates, crinoid stems)

Limestone, argillaceous, buff-grey, marcasite, fossils
(Lingula cf. ligea, Schizophoria cf. iowensis)

292 Shale, calcareous, green-grey, fossils

296 (Productella sp.)
(Schizophoria, Trochiliscids)

Limestone, argillaceous, buff-grey, fossils
(Atrypa devoniana, Stropheodonta demissa)

315

(Twinned marcasite)

(Atrypa devoniana, Spirifer allani)

Shale, calcareous, green-grey, fragmental
(Scattered marcasite replaced plant remains)
(Spinorbis omphaloides, Atrypa devoniana, crinoid stems)
(Rhombopora sp.)

386

Limestone, argillaceous, grey-brown, marcasite
(Atrypa devoniana)

402

406 Shale, calcareous, green-grey, fragmental

412 Limestone, argillaceous, grey-brown

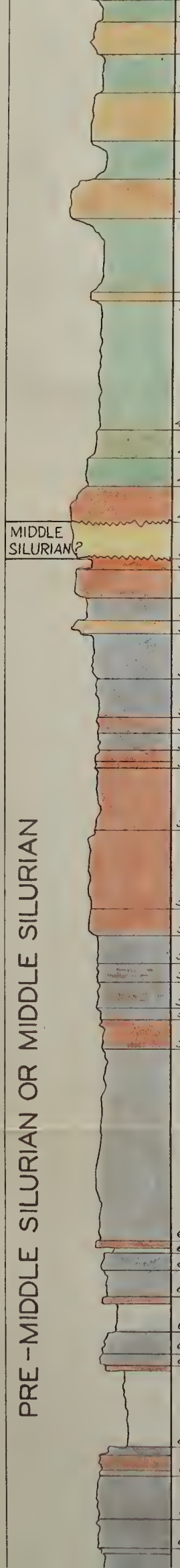
419 Shale, calcareous, green-grey, some banding

Limestone, argillaceous, brown-grey

428

Shale, calcareous, green-grey, fragmental, marcasite, fossils
435 (Atrypa devoniana, Lingula cf. ligea, Spirifer allani)

Limestone, mottled, fossils
442 (Schizophoria iowensis, Atrypa devoniana, Atrypa sp.



406 Shale, calcareous, green-grey, fragmental

412 Limestone, argillaceous, grey-brown

419 Shale, calcareous, green-grey, some banding

428 Limestone, argillaceous, brown-grey

435 Shale, calcareous, green-grey, fragmental, marcasite, fossils
(Atrypa devoniana, Lingula cf. ligea, Spirifer allani)

442 Limestone, mottled, fossils
(Schizophoria iowensis, Atrypa devoniana, Atryna sp. straight beaked)

455 Shale, calcareous, green-grey, fragmental, fossils
(Lingula cf. ligea, Tentaculites mackenziensis, fish jaw)

457 Limestone, argillaceous, brown-grey, marcasite

480 Shale, calcareous, green-grey, fragmental, fossils
(Atrypa albertensis, Atrypa devoniana, Leptodesma sp., Lingula cf. ligea)
(Tentaculites mackenziensis)

485 Shale, calcareous and argillaceous limestone interbeds
(Lingula, Tentaculites)

490 Shale, calcareous, green-grey, fragmental, fossils

497 Limestone, grey-brown, carbonaceous, marcasite
(Atrypa devoniana, Athyris, Paracyclas, nautiloids)

MIDDLE SILURIAN?

503 Limestone and dolomitic limestone, interbands, dark brown, platy and buff finely bedded, satin spar bands

505 Rock gypsum, 2-foot band, white and powdery to brown crystalline

510 Dolomite, buff, and rock gypsum

514 Anhydrite, dolomitic, brown-grey

516 Limestone, grey-buff

524 Anhydrite, dolomitic, grey-buff, salty

531 Anhydrite, mottled, dolomitic, salty, grey-buff

534 Dolomite, buff, satin spar bands

537 Anhydrite, crystalline, in buff dolomite

540 Dolomite, grey, salty, satin spar bands

551 Dolomite, anhydrite, gypsum and salt, mottled

Dolomite, green-grey, salty

565 Dolomite, brown-grey and green-grey, salty, satin spar bands and veins

570 Dolomite, buff-brown with dolomitic crystalline replacements

575 Anhydrite, colorless, some mottling, buff dolomite

578 Anhydrite, dolomitic, maroon and green-grey, salty

583 Anhydrite, colorless, some salty grey dolomite streaks

585 Anhydrite, colorless, with maroon and grey salty dolomite

590 Anhydrite, buff, dolomitic

Dolomite, green-grey, salty, satin spar

Anhydrite, mottled with buff dolomite and green-grey salty dolomite, satin spar bands in the greyer

PRE-MIDDLE SILURIAN OR MIDDLE SILURIAN

625 Dolomite, buff, anhydrite replacements

627 Saline washings, no core

630 Anhydrite, dolomitic, brown

635 Anhydrite, porous, buff, salty

641 Dolomite, buff, salty

645 No core, saline washings

647 Anhydrite and salt in dolomite matrix

Anhydrite, dolomitic, mottled, buff and colorless

Dolomite, salty, green-grey

662 Rock salt, colorless

667 Anhydrite, mottled with buff dolomite

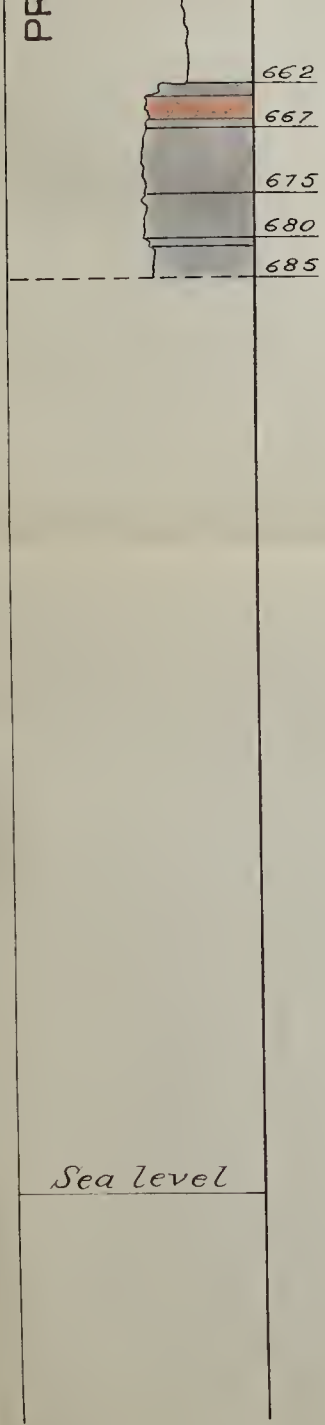
675 Dolomite, satin spar and anhydrite interbands

680 Anhydrite, mottled with brown dolomite

Anhydrite and dolomite, much granular salt

Anhydrite, mottled with buff dolomite, grades to blue-grey and buff

Anhydrite, dolomitic, irregular rock salt bands




Rock salt, colorless

662 Anhydrite, mottled with buff dolomite

667 Dolomite, satin spar and anhydrite interbands

Anhydrite, mottled with brown dolomite

Anhydrite and dolomite, much granular salt

675 Anhydrite, mottled with buff dolomite, grades to blue-grey and buff

680 Anhydrite, dolomitic, irregular rock salt bands

685 Anhydrite, dolomitic, mottled blue-grey and brown

Bottom of well at 685'

To accompany Thesis- W.D. MacDonald, 1947.

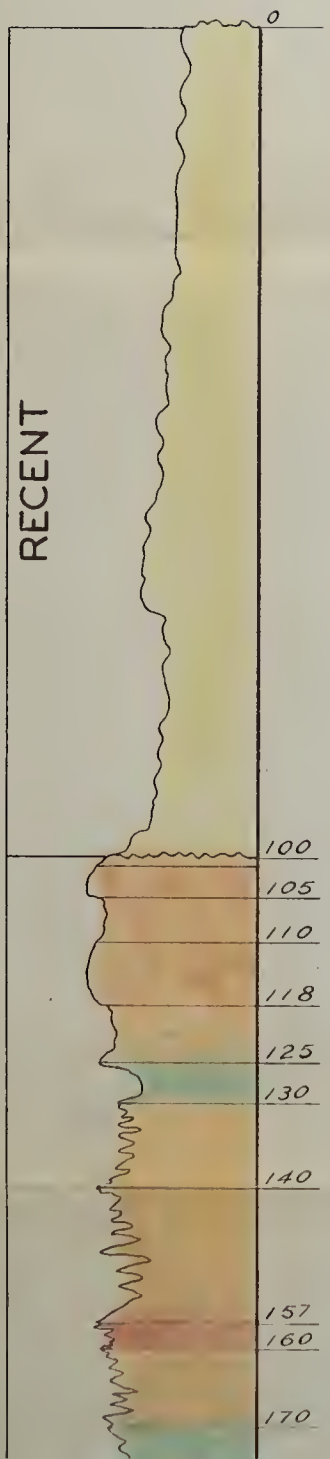
# SALT WELL NO. 1

## INDUSTRIAL MINERALS LTD.

## WATERWAYS-ALBERTA

SCALE: 1" TO 20 FEET

S.E ¼. SEC. 10. TP. 89. RG. 9. W. 4TH.
589' SOUTHWEST OF WATERWAYS STATION
72' FROM SOUTHEAST END SALT PLANT
ELEVATION 825 FEET ABOVE SEA LEVEL.




Unconsolidated sediments

Limestone, argillaceous, brown-grey

Limestone, mottled, buff and grey, marcasite, fossils (Spirifer allani, crinoid stems)

Limestone, argillaceous, grey-buff and buff-grey banded

Limestone, mottled, buff and grey-brown, marcasite, fossils (Athyris sp., Spirifer allani, Atrypa devoniana)

Limestone, argillaceous, grey-buff, some green-grey, marcasite

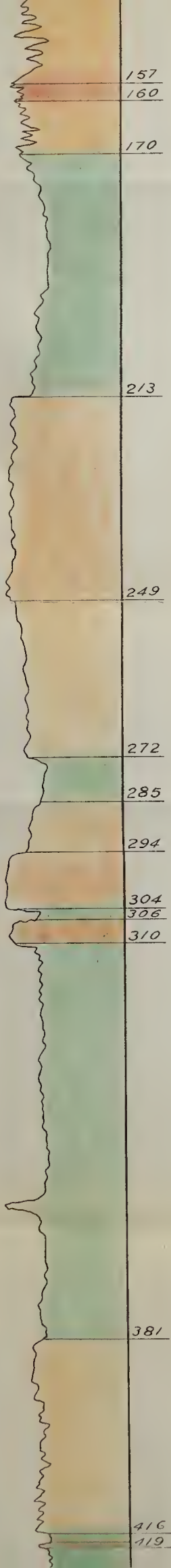
Shale, calcareous, green-grey, fragmental, marcasite (Pachypora type)

Limestone, argillaceous, brown-grey, with interbedded calcareous shale

Limestone, argillaceous, buff-grey, and interbedded shale, calcareous, green-grey, fragmental

Limestone, crystalline, brown, and argillaceous limestone (Atrypa devoniana, conodonts, crinoid stems)

Limestone, argillaceous, brown-grey and green-grey, calcareous shale interbeds



UPPER DEVONIAN

Limestone, argillaceous, buff-grey, and interbedded shale, calcareous, green-grey, fragmental

157 Limestone, crystalline, brown, and argillaceous limestone
160 (Atrypa devoniana, conodonts, crinoid stems)

Limestone, argillaceous, brown-grey and green-grey, calcareous shale interbeds
170

Shale, calcareous, green-grey, fragmental

213

(Atrypa devoniana, Atrypa albertensis, Bryozoa, Cyrtina billingsi, Schizophoria cf. iowensis, Stropheodonta sp.)

Limestone, mottled, grey-brown, and grey, marcasitic and fossiliferous
(Crinoid stems)

(Atrypa albertensis, Atrypa devoniana, crinoid stems, Productella sp., Stropheodonta demissa)
249 (Atrypa devoniana, Stropheodonta demissa, Stropheonella sp.)

Limestone, argillaceous, grey-brown, marcasite, fossils

(Atrypa devoniana, Chonetes sp., Productella sp., Stropheodonta demissa)
(Atrypa devoniana, pelecypod - Leda?, Pugnax pugnus, Schizophoria cf. iowensis, Stropheodonta demissa,
272 Stropheonella sp.)
Shale, calcareous, green-grey, fossils (Atrypa devoniana, Lingula cf.
285 ligea, Schizophoria cf. iowensis, Stropheodonta demissa, crinoid stems)

Limestone, argillaceous, grey-brown, calcareous shale interbeds,
294 marcasite, fossils (Lingula cf. ligea, Schizophoria cf. iowensis)
Limestone, mottled, colorless, crystalline and grey-brown, fossils
(Atrypa devoniana, crinoid stems, Cyrtina billingsi, Schizophoria
304 iowensis, Spirifer allani, Stropheodonta demissa, Stropheonella sp.,
306 Shale, calcareous, green-grey Trochiliscids)
310 Limestone, mottled, grey-brown and grey, fossils, marcasite
(Atrypa devoniana, Stropheodonta sp., crinoid stems, Spirifer allani)

(Algae)
(Atrypa devoniana, crinoid stems, fish plates)

Shale, calcareous, green-grey, fossils, and marcasite bands, marcasitic plant remains
(Atrypa devoniana, crinoid stems, Cyrtina billingsi, Stylioline fissurella)
(Atrypa devoniana, Cyrtina billingsi, Spirifer allani)

Marcasitic band
(Atrypa devoniana, Cyrtina, fish plates, Leptodesma, Spirifer allani, marcasite replaced fossils)

381 (Atrypa devoniana, Lingula cf. ligea, Orbiculoidea sp.)

Limestone, argillaceous, grey-brown, interbeds of calcareous shale, green-grey

(Crinoid stems, Cyrtina billingsi, Leptodesma)
416 Shale, calcareous, green-grey, marcasite and fossils
419 Limestone, argillaceous, grey-brown, marcasite

(Crinoid stems, Cyrtina billingsi, Leptodesma)

416 Shale, calcareous, green-grey, marcasite and fossils

419 Limestone, argillaceous, grey-brown, marcasite

Shale, calcareous, green-grey, marcasite, very fossiliferous (Atrypa devoriana, Atrypa straight beaked var., Crania famelica, Cyrtina billingsi, Leptodesma, Lingula cf. ligea, Spirifer delthyris)

428

432 Limestone, argillaceous, brown-grey, and calcareous shale interbeds (Leptodesma, Lingula cf. ligea)

Shale, calcareous, green-grey (Leptodesma, Lingula cf. ligea, Atrypa devoniana, Cyrtina billingsi)

445

447 Limestone, mottled, brown and green-grey, marcasite Nodules (Atrypa devoniana, Leptodesma) Nodules

Shale, calcareous, green-grey, fragmental, fossils (Lingula cf. ligea, Tentaculites mackenziensis - 460') (Leptodesma, fish plates)

(Tentaculites mackenziensis)

484 Shale, calcareous, brown, platy, nodules (Lingula cf. ligea)

487 Limestone, buff-brown, anhydrite replacement, marcasite, fossils

490 Limestone, buff-grey, marcasite, fossils (Atrypa devoniana, Nautiloids,

MIDDLE SILURIAN? 494 Limestone, dolomitic, buff, platy, fine-bedded Gastropods)

497 **Limestone, buff, brown gypsum replacements**

Rock Gypsum, crystalline dark brown, some dolomite, satin spar

Anhydrite, with crystalline gypsum replacements, grades to buff

506 dolomitic anhydrite

511 Limestone, buff-brown, satin spar, and grey dolomitic anhydrite

513 Anhydrite, mottled, with buff dolomite, grey salty dolomite bands

518 Anhydrite and dolomite, satin spar veining, salty, interbedded

523 Dolomite, dark grey-brown, salty, anhydrite veins, satin spar veins

530 Anhydrite, crystalline, mottled with some buff dolomite

Dolomite, green-grey, salty, with some anhydrite, satin spar bands

538 Dolomite, green-grey and maroon splotched, salty, pink satin spar veins, some dolomitic anhydrite interbands

Dolomite, buff, with large colorless crystalline anhydrite vugs

546 Dolomite, dark brown, finely bedded, salty, satin spar veins, some anhydrite

551 Dolomite, green-grey and maroon splotched, some anhydrite

555 Anhydrite, dolomitic, grey-brown, salty, grades to buff dolomitic anhydrite

560 Dolomite, dark brown, salty, pink satin spar veining, anhydrite inclusions

Anhydrite, dolomitic, splotched maroon and green-grey

570

Anhydrite, crystalline, mottled with buff dolomite

575 Limestone, dolomitic, maroon and green-grey splotched, salty

Anhydrite, colorless, crystalline, mottled with salty, grey dolomite, some satin spar veins and interbands

620

622 Limestone, dolomitic, buff

624 Anhydrite, crystalline, dolomitic, mottled, colorless and buff

626 Dolomite, dark grey, salty, some anhydrite

Anhydrite, crystalline, dolomitic, mottled blue-grey and buff

657

660 Dolomite, buff, vugs of colorless anhydrite, interbeds of crystalline dolomitic anhydrite

Anhydrite, finely crystalline, dolomitic, mottled grey and brown

670

Dolomite, buff and grey, salty, satin spar veins and interbands, some anhydrite

680 Anhydrite, crystalline, buff, dolomitic

crystalline dolomitic anhydrite

Anhydrite, finely crystalline, dolomitic, mottled grey and brown

Dolomite, buff and grey, salty, satin spar veins and interbands, some anhydrite

Anhydrite, crystalline, buff, dolomitic

Dolomite, buff, salty, some anhydrite

Anhydrite, crystalline, mottled with buff dolomite

Dolomite, buff, finely bedded, satin spar veins and interbeds, salty

Anhydrite, finely crystalline, mottled with buff dolomite, irregular contact

Rock Salt, crystalline colorless, transparent

Anhydrite, crystalline, mottled with buff dolomite

Limestone, porous, buff, thin bedded, some satin spar interbands and anhydrite

Bottom of well

# TABLE Nº I

## CORRELATION OF FAUNA AND FLORA IN THE WATERWAYS FORMATION AT WATERWAYS AND McMURRAY ALBERTA

### ALBERTA GOVERNMENT SALT WELL Nº 1 McMURRAY ALBERTA

MACDONALD W.D. MASTERS THESIS 1947.

**FORMATION ○ PORTAGE ~ NAPLES AGE**

**LIME STONE — MOTTLED & ARGILLACEOUS BUFF AND GREY BUFF**

- 96 — 100 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS; SPIRIFER ALLANI WARREN
- 131 — CRINOID STEMS ; SPIRIFER ALLANI WARREN
- 160 — ATRYPA RETICULARIS (LINN.) ; CRINOID STEMS; SPIRIFER ALLANI WARREN
- 164
- 170 — SPIRIFER ALLANI WARREN ; TROCHILISCIDS

**SHALE — CALCAREOUS GREEN GREY**

- 200

**LIMESTONE — ARGILLACEOUS GREY BUFF**

- 223 — ATRYPA ALBERTENSIS WARREN; ATRYPA DEVONIANA WEBSTER; SCHIZOPHORIA CF. IOWENSIS HALL; STROPHEODONTA SP.
- 230
- 239 — ATRYPA DEVONIANA WEBSTER ; CRINOID STEMS; CYRTINA BILLINGSI MEEK; STROPHEODONTA INEQUIRADIATA HALL; SPIRORBIS OMPHALOIDES GOLDFUSS
- 241 — ATRYPA DEVONIANA WEBSTER; SCHIZOPHORIA CF. IOWENSIS HALL
- 250 — STROPHEODONTA DEMISSA (CONRAD)
- 257 — STROPHEODONTA DEMISSA (CONRAD)
- 264 — STROPHEODONTA DEMISSA (CONRAD)
- 270 — PLECYPOD – LEDA?
- 276 — CRANIA FAMELICA H.&W. ; CRINOID STEMS; GLYPTASPIS; SCHIZOPHORIA CF. IOWENSIS HALL; STROPHEODONTA DEMISSA (CONRAD)
- 285 — CRINOID STEM ; LINGULA CF. LIGEA HALL; SCHIZOPHORIA CF. IOWENSIS HALL
- 292
- 296 — CRINOID STEMS ; PRODUCTELLA SP. ; TROCHILISCIDS
- 300 — SCHIZOPHORIA CF. IOWENSIS HALL
- 301 — ATRYPA DEVONIANA WEBSTER ; CRINOID STEMS
- 307 — SCHIZOPHORIA CF. IOWENSIS HALL; TROCHILISCIDS
- 312
- 315 — ATRYPA DEVONIANA WEBSTER ; CRINOID STEMS; STROPHEODONTA DEMISSA (CONRAD)

**SHALE — CALCAREOUS GREEN GREY**

- 328 — ATRYPA DEVONIANA WEBSTER ; PLANT FRAGMENTS; SPIRIFER ALLANI WARREN
- 340 — ATRYPA DEVONIANA WEBSTER ; CRINOID STEMS; SPIRORHIS OMPHALOIDES GOLDFUSS; RHOMBOPORA SP.
- 354 — ATRYPA DEVONIANA WEBSTER ; CRINOID STEMS
- 364 — ATRYPA DEVONIANA WEBSTER

### INDUSTRIAL MINERALS LTD. COTTEE Nº 1 SALT WELL WATERWAYS ALBERTA

ALLEN J.A. ALTA. RES. COUNCIL REPORT Nº 34, 1943.

**WATERWAYS – RECENT CONTACT**

**LIMESTONE**

- 100 — SPIRIFER CF. TULLIA HALL

**SHALE — CALCAREOUS**

- 170
- 200

**LIMESTONE — MOTTLED AND ARGILLACEOUS**

- 213 — ATRYPA RETICULARIS (LINN)
- 273 — STROPHEODONTA SP.
- 277 — SCHIZOPHORIA STRIATULA (SCHLOT.)
- 300
- 310

**SHALE — CALCAREOUS**

- 337 — SCHIZOPHORIA STRIATULA (SCHLOT.); ATRYPA RETICULARIS (LINN.)
- 349 — SCHIZOPHORIA STRIATULA (SCHLOT.); ATRYPA RETICULARIS (LINN.)

### INDUSTRIAL MINERALS LTD. COTTEE Nº 1 SALT WELL WATERWAYS ALBERTA

MACDONALD W.D. MASTERS THESIS 1947.

**LIME STONE**

- 100 — 101 — CRINOID STEMS ; SPIRIFER ALLANI WARREN
- ATHYRIS SP. ; ATRYPA DEVONIANA WEBSTER; SPIRIFER ALLANI WARREN
- 118 — PACHYPORA TYPE CORAL
- 131
- 160 — ATRYPA DEVONIANA; CONODONTS; CRINOID STEMS
- 170

**SHALE — CALCAREOUS**

- ATRYPA ALBERTENSIS WARREN; ATRYPA DEVONIANA WEBSTER; BRYOZOA ; CYRTINA BILLINGSI MEEK ; CRINOID STEMS; SCHIZOPHORIA CF. IOWENSIS HALL; STROPHEODONTA SP.
- 200 — ATRYPA ALBERTENSIS WARREN ; ATRYPA DEVONIANA WEBSTER; CRINOID STEMS; PRODUCTELLA SP.; STROPHEODONTA DEMISSA (CONRAD)
- 213 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS; STROPHEODONTA DEMISSA (CONRAD); STROPHEONELLA SP.

**LIMESTONE — MOTTLED**

- 229 — ATRYPA DEVONIANA WEBSTER ; CHONETES SP.; CRINOID STEMS ; PRODUCTELLA SP.; STROPHEODONTA DEMISSA (CONRAD)
- 237 — ATRYPA DEVONIANA WEBSTER ; PLECYPOD – LEDA?; PUGNAX PUGNUS (MARTIN); STROPHEONELLA; SCHIZOPHORIA CF. IOWENSIS HALL
- 249
- 254 — ATRYPA DEVONIANA WEBSTER ; CRINOID STEMS.; LINGULA CF. LIGEA HALL; STROPHEODONTA DEMISSA (CONRAD); SCHIZOPHORIA CF. IOWENSIS HALL
- 265 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS; CYRTINA BILLINGSI MEEK ; SCHIZOPHORIA CF. IOWENSIS HALL; SPIRIFER ALLANI WARREN; STROPHEODONTA DEMISSA (CONRAD); STROPHEONELLA SP. ; TROCHILISCIDS
- 271
- 277
- 282 — ATRYPA DEVONIANA WEBSTER; STROPHEODONTA SP.
- 285
- 294 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS; SPIRIFER ALLANI WARREN
- 300
- 306 — ALGAE
- 310 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS ; FISH PLATES
- 314

**SHALE — CALCAREOUS**

- 322 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS; CYRTINA BILLINGSI MEEK; STYLIOLINA FISSURELLA HALL
- 325
- 331 — ATRYPA DEVONIANA WEBSTER; CYRTINA BILLINGSI MEEK; SPIRIFER ALLANI WARREN
- 338 — ATRYPA DEVONIANA WEBSTER ; CRINOID STEMS; CYRTINA BILLINGSI MEEK ; FISH PLATES; LEPTODESMA SP. ?; SPIRIFER ALLANI WARREN
- 345
- 354 — LINGULA CF. LIGEA HALL ; ORBICULOIDEA SP.

**LIMESTONE**

**SHALE**

# TABLE N°1
## AND FLORA IN THE WATERWAYS FORMATION
## AND McMURRAY ALBERTA

SALT WELL
1943.

ONTACT

LARIS (LINN)
LARIS (LINN)

INDUSTRIAL MINERALS LTD. COTTEE N°1 SALT WELL
WATERWAYS ALBERTA
MACDONALD W.D. MASTERS THESIS 1947.

INDUSTRIAL MINERALS LTD. N°3 SALT WELL
(INCOMPLETE LOG) WATERWAYS ALBERTA
MACDONALD W.D. MASTERS THESIS 1947.

| | | | |
|---|---|---|---|
| | 100 | CRINOID STEMS ; SPIRIFER ALLANI WARREN | |
| | 101 | ATHYRIS SP. ; ATRYPA DEVONIANA WEBSTER<br>SPIRIFER ALLANI WARREN | |
| LIMESTONE | 118 | PACHYPORA TYPE CORAL | |
| | 131 | | |
| | 151 | | LS. MOTTLED BUFF & GREY BUFF |
| | 160 | ATRYPA DEVONIANA ; CONODONTS<br>CRINOID STEMS | |
| | 164 | | |
| | 170 | | |
| SHALE CALCAREOUS | 200 | ATRYPA ALBERTENSIS WARREN ; ATRYPA DEVONIANA WEBSTER<br>BRYOZOA ; CYRTINA BILLINGSI MEEK ; CRINOID STEMS<br>SCHIZOPHORIA CF. IOWENSIS HALL ; STROPHEADONTA SP. | SHALE CALCAREOUS GREEN GREY |
| | 200 | ATRYPA ALBERTENSIS WARREN ; ATRYPA DEVONIANA WEBSTER<br>CRINOID STEMS ; PRODUCTELLA SP.<br>STROPHEODONTA DEMISSA (CONRAD) | |
| | 213 | ATRYPA DEVONIANA WEBSTER ; CRINOID STEMS<br>STROPHEODONTA DEMISSA (CONRAD) ; STROPHEONELLA SP. | |
| | 229 | ATRYPA DEVONIANA WEBSTER ; CHONETES SP.<br>CRINOID STEMS ; PRODUCTELLA SP.<br>STROPHEODONTA DEMISSA (CONRAD) | |
| | 237 | ATRYPA DEVONIANA WEBSTER ; PLECYPOD – LEDA?<br>PUGNAX PUGNUS (MARTIN) ; STROPHEONELLA<br>SCHIZOPHORIA CF. IOWENSIS HALL | |
| LIMESTONE MOTTLED | 249 | | |
| | 254 | ATRYPA DEVONIANA WEBSTER ; CRINOID STEMS.<br>LINGULA CF. LIGEA HALL ; STROPHEODONTA DEMISSA (CONRAD)<br>SCHIZOPHORIA CF. IOWENSIS HALL | |
| | 250 | | LIMESTONE MOTTLED & ARGILLACEOUS BUFF AND GREY BUFF |
| | 265 | ATRYPA DEVONIANA WEBSTER ; CRINOID STEMS<br>CYRTINA BILLINGSI MEEK ; SCHIZOPHORIA CF IOWENSIS HALL<br>SPIRIFER ALLANI WARREN ; STROPHEODONTA DEMISSA (CONRAD)<br>STROPHEONELLA SP ; TROCHILISCIDS | ATRYPA DEVONIANA WEBSTER ; FISH PLATES |
| | 271 | | |
| | 277 | | |
| | 282 | | |
| | 285 | ATRYPA DEVONIANA WEBSTER<br>STROPHEODONTA SP. | |
| | 290 | | FISH PLATES ; CRINOID STEMS<br>STROPHEODONTA CF. NAVALIS SWALLOW |
| | 294 | ATRYPA DEVONIANA WEBSTER ; CRINOID STEMS<br>SPIRIFER ALLANI WARREN | |
| | 300 | | STROPHEODONTA CF. CALLAWAYENSIS SWALLOW |
| | 306 | ALGAE | |
| | 310 | ATRYPA DEVONIANA WEBSTER<br>CRINOID STEMS ; FISH PLATES | |
| | 314 | | |
| SHALE CALCAREOUS | 322 | ATRYPA DEVONIANA WEBSTER ; CRINOID STEMS<br>CYRTINA BILLINGSI MEEK ; STYLIOLINA FISSURELLA HALL | |
| | 325 | | |
| | 330 | | ATRYPA DEVONIANA WEBSTER ; STROPHEODONTA SP. |
| | 331 | ATRYPA DEVONIANA WEBSTER<br>CYRTINA BILLINGSI MEEK ; SPIRIFER ALLANI WARREN | |
| | 338 | | |
| | 340 | | CRINOID STEMS ; TROCHILISCIDS |
| | 345 | ATRYPA DEVONIANA WEBSTER ; CRINOID STEMS<br>CYRTINA BILLINGSI MEEK ; FISH PLATES<br>LEPTODESMA SP. ?<br>SPIRIFER ALLANI WARREN | |
| | 354 | | |

FORMATION ~ PORTAGE ~ NAPLES AGE

# WATERWAYS FORMATION • PORTAGE ~ NAPLES

## WATERWAYS

### LIMESTONE ARGILLACEOUS GREY BUFF

223 — ATRYPA ALBERTENSIS WARREN; ATRYPA DEVONIANA WEBSTER; SCHIZOPHORIA CF. IOWENSIS HALL; STROPHEODONTA SP.
230
239 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS; CYRTINA BILLINGSI MEEK; STROPHEODONTA INEQUIRADIATA HALL; SPIRORBIS OMPHALOIDES GOLDFUSS
241 — ATRYPA DEVONIANA WEBSTER; SCHIZOPHORIA CF. IOWENSIS HALL
250 — STROPHEODONTA DEMISSA (CONRAD)
257 — STROPHEODONTA DEMISSA (CONRAD)
264 — STROPHEODONTA DEMISSA (CONRAD)
270 — PLECYPOD – LEDA?
276 — CRANIA FAMELICA H.&W.; CRINOID STEMS; GLYPTASPIS; SCHIZOPHORIA CF. IOWENSIS HALL; STROPHEODONTA DEMISSA (CONRAD)
285 — CRINOID STEM; LINGULA CF. LIGEA HALL; SCHIZOPHORIA CF. IOWENSIS HALL
292
296 — CRINOID STEMS; PRODUCTELLA SP.; TROCHILISCIDS
300 — SCHIZOPHORIA CF. IOWENSIS HALL
301 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS
307 — SCHIZOPHORIA CF. IOWENSIS HALL; TROCHILISCIDS
312

### SHALE CALCAREOUS GREEN GREY

315 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS; STROPHEODONTA DEMISSA (CONRAD)
328 — ATRYPA DEVONIANA WEBSTER; PLANT FRAGMENTS; SPIRIFER ALLANI WARREN
340 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS; SPIRORHIS OMPHALOIDES GOLDFUSS; RHOMBOPORA SP.
354 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS
364 — ATRYPA DEVONIANA WEBSTER

### LIMESTONE – ARG. SHALE – CALC.

386
391 — ATRYPA DEVONIANA WEBSTER
400 — ATRYPA DEVONIANA WEBSTER

428 — ATRYPA DEVONIANA WEBSTER; LINGULA CF. LIGEA HALL; SPIRIFER ALLANI WARREN
435 — ATRYPA DEVONIANA WEBSTER; ATRYPA SP. (STRAIGHT-BEAKED VAR.)
442 — SCHIZOPHORIA CF IOWENSIS HALL; PELECYPOD UNDET
450 — FISH JAW; LINGULA CF. LIGEA HALL
453 — TENTACULITES MACKENZIENSIS KINDLE
457

### SHALE CALCAREOUS GREEN GREY

ATRYPA ALBERTENSIS WARREN; FISH PLATES
ATRYPA DEVONIANA WEBSTER; LEPTODESMA SP.
LINGULA CF. LIGEA HALL
475
478 — LINGULA CF. LIGEA HALL; TENTACULITES MACKENZIENSIS KINDLE
485

### LS

490
497 — ATRYPA ALBERTENSIS WARREN; ATHYRIS SP.
500 — ATRYPA DEVONIANA WEBSTER; CONODONTS; NAUTILOIDS – ORTHOCERAS TYPE; PARACYCLAS CF. ELLIPTICA HALL

## WATERWAYS

### LIMESTONE MOTTLED AND ARGILLACEOUS

213
227 — ATRYPA RETICULARIS (LINN)
273 — STROPHEODONTA SP.
277 — SCHIZOPHORIA STRIATULA (SCHLOT.)
300

### SHALE CALCAREOUS

310
337 — SCHIZOPHORIA STRIATULA (SCHLOT.); ATRYPA RETICULARIS (LINN)
349 — SCHIZOPHORIA STRIATULA (SCHLOT.); ATRYPA RETICULARIS (LINN)
367 — ATRYPA RETICULARIS (LINN)
381

### LIMESTONE – ARG. SHALE – CALC.

400
422 — SCHIZOPHORIA STRIATULA (SCHLOT.); ATRYPA RETICULARIS (LINN.); CYRTINA BILLINGSI MEEK
423 — ATRYPA RETICULARIS (LINN)
426 — ATRYPA RETICULARIS (LINN)

### SHALE CALCAREOUS

446
456 — LINGULA SPATULATA VANUX

### LS

485
500

WATERWAYS – MIDDLE SILURIAN CONTACT

## WATERWAYS

### LIMESTONE MOTTLED

213
ATRYPA DEVONIANA WEBSTER; CRINOID STEMS; STROPHEODONTA DEMISSA (CONRAD); STROPHEONELLA SP.
229 — ATRYPA DEVONIANA WEBSTER; CHONETES SP.; CRINOID STEMS; PRODUCTELLA SP.; STROPHEODONTA DEMISSA (CONRAD)
237 — ATRYPA DEVONIANA WEBSTER; PLECYPOD – LEDA?; PUGNAX PUGNUS (MARTIN); STROPHEONELLA; SCHIZOPHORIA CF. IOWENSIS HALL
249
254 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS; LINGULA CF. LIGEA HALL; STROPHEODONTA DEMISSA (CONRAD); SCHIZOPHORIA CF. IOWENSIS HALL
265 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS; CYRTINA BILLINGSI MEEK; SCHIZOPHORIA CF IOWENSIS HALL; SPIRIFER ALLANI WARREN; STROPHEODONTA DEMISSA (CONRAD); STROPHEONELLA SP.; TROCHILISCIDS
271
277
282
285 — ATRYPA DEVONIANA WEBSTER; STROPHEODONTA SP.
294 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS; SPIRIFER ALLANI WARREN
300
ALGAE
306
310 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS; FISH PLATES
314

### SHALE CALCAREOUS

322 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS; CYRTINA BILLINGSI MEEK; STYLIOLINA FISSURELLA HALL
325
331 — ATRYPA DEVONIANA WEBSTER; CYRTINA BILLINGSI MEEK; SPIRIFER ALLANI WARREN
338 — ATRYPA DEVONIANA WEBSTER; CRINOID STEMS; CYRTINA BILLINGSI MEEK; FISH PLATES; LEPTODESMA SP.?; SPIRIFER ALLANI WARREN
345
354 — ATRYPA DEVONIANA WEBSTER; LINGULA CF. LIGEA HALL; ORBICULOIDEA SP.
368
378
381

### LIMESTONE – ARG. SHALE – CALC.

CRINOID STEMS; LEPTODESMA SP.; CYRTINA BILLINGSI MEEK
400 — ATRYPA DEVONIANA WEBSTER; ATRYPA STRAIGHT-BEAKED VAR.; CRANIA FAMELICA H.&W.; CYRTINA BILLINGSI MEEK; LEPTODESMA SP.; LINGULA CF. LIGEA; MODIOMORPHA SP.; SPIRIFER DELTHYRIS
416
419
428
432 — ATRYPA DEVONIANA WEBSTER; CYRTINA BILLINGSI MEEK; LEPTODESMA SP.; LINGULA CF. LIGEA HALL
445

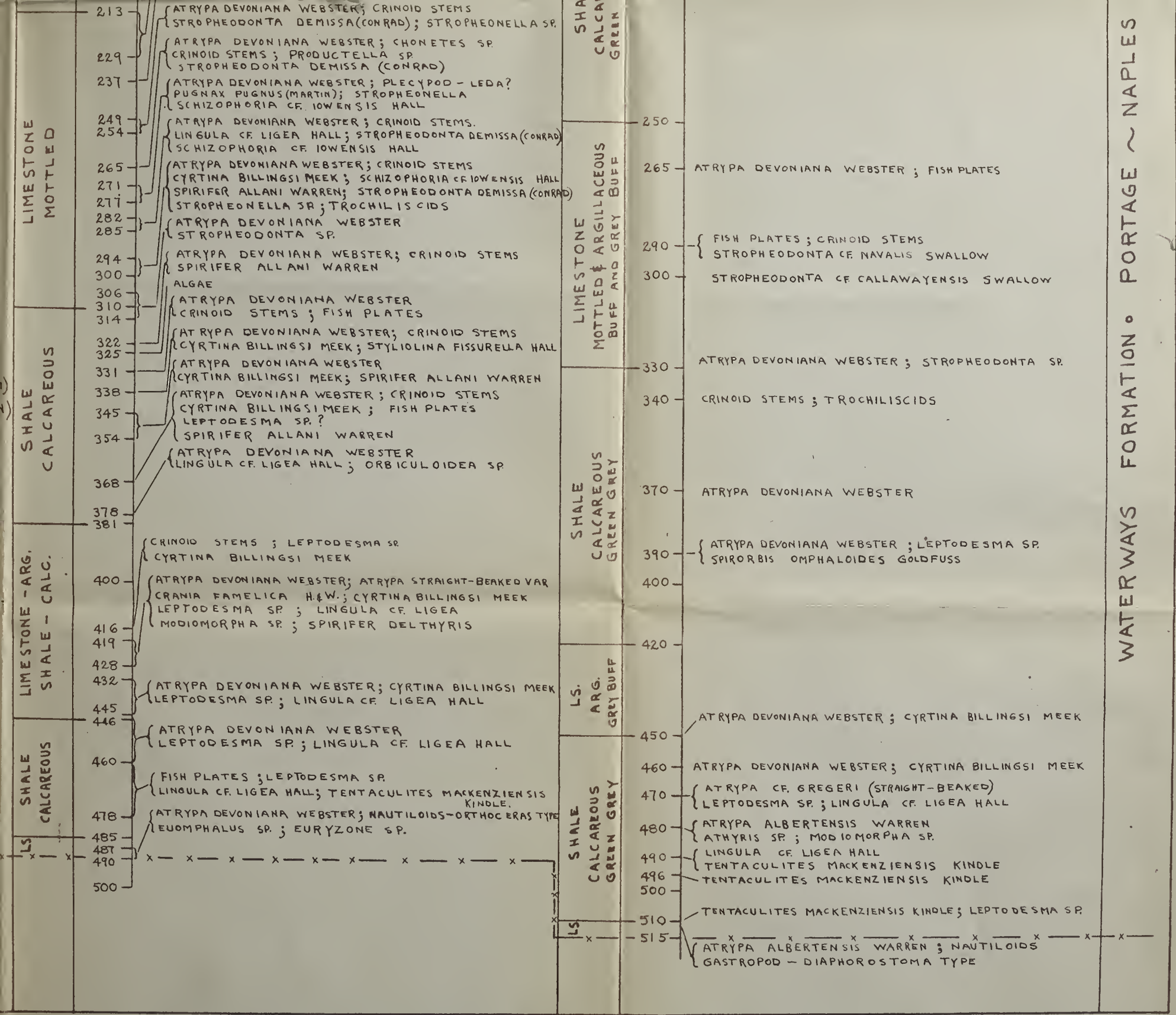
### SHALE CALCAREOUS

446
ATRYPA DEVONIANA WEBSTER; LEPTODESMA SP.; LINGULA CF. LIGEA HALL
460 — FISH PLATES; LEPTODESMA SP.; LINGULA CF. LIGEA HALL; TENTACULITES MACKENZIENSIS KINDLE.
478 — ATRYPA DEVONIANA WEBSTER; NAUTILOIDS – ORTHOCERAS TYPE; EUOMPHALUS SP.; EURYZONE SP.

### LS

485
487
490
500

• TO ACCOMPANY M.SC. THESIS – MACDONALD W.D. 1947 •


WATERWAYS FORMATION • PORTAGE ~ NAPLES
LIMESTONE MOTTLED
SHALE CALCAREOUS
LIMESTONE - ARG. SHALE - CALC.
SHALE CALCAREOUS
LS
SHALE CALCAREOUS GREEN GREY
LIMESTONE MOTTLED & ARGILLACEOUS BUFF AND GREY BUFF
SHALE CALCAREOUS GREEN GREY
LS. ARG. GREY BUFF
SHALE CALCAREOUS GREEN GREY
LS
213 ATRYPA DEVONIANA WEBSTER; CRINOID STEMS
STROPHEODONTA DEMISSA (CONRAD); STROPHEONELLA SP.
229 ATRYPA DEVONIANA WEBSTER; CHONETES SP.
CRINOID STEMS; PRODUCTELLA SP.
STROPHEODONTA DEMISSA (CONRAD)
237 ATRYPA DEVONIANA WEBSTER; PLECYPOD - LEDA?
PUGNAX PUGNUS (MARTIN); STROPHEONELLA
SCHIZOPHORIA CF. IOWENSIS HALL
249 ATRYPA DEVONIANA WEBSTER; CRINOID STEMS.
254 LINGULA CF. LIGEA HALL; STROPHEODONTA DEMISSA (CONRAD)
SCHIZOPHORIA CF. IOWENSIS HALL
265 ATRYPA DEVONIANA WEBSTER; CRINOID STEMS
271 CYRTINA BILLINGSI MEEK; SCHIZOPHORIA CF. IOWENSIS HALL
277 SPIRIFER ALLANI WARREN; STROPHEODONTA DEMISSA (CONRAD)
STROPHEONELLA SP; TROCHILISCIDS
282 ATRYPA DEVONIANA WEBSTER
285 STROPHEODONTA SP.
294 ATRYPA DEVONIANA WEBSTER; CRINOID STEMS
300 SPIRIFER ALLANI WARREN
ALGAE
306 ATRYPA DEVONIANA WEBSTER
310 CRINOID STEMS; FISH PLATES
314
322 ATRYPA DEVONIANA WEBSTER; CRINOID STEMS
325 CYRTINA BILLINGSI MEEK; STYLIOLINA FISSURELLA HALL
331 ATRYPA DEVONIANA WEBSTER
338 CYRTINA BILLINGSI MEEK; SPIRIFER ALLANI WARREN
345 ATRYPA DEVONIANA WEBSTER; CRINOID STEMS
CYRTINA BILLINGSI MEEK; FISH PLATES
354 LEPTODESMA SP.?
SPIRIFER ALLANI WARREN
ATRYPA DEVONIANA WEBSTER
368 LINGULA CF. LIGEA HALL; ORBICULOIDEA SP.
378
381
CRINOID STEMS; LEPTODESMA SP.
CYRTINA BILLINGSI MEEK
400 ATRYPA DEVONIANA WEBSTER; ATRYPA STRAIGHT-BEAKED VAR
CRANIA FAMELICA H.&W.; CYRTINA BILLINGSI MEEK
LEPTODESMA SP.; LINGULA CF. LIGEA
416 MODIOMORPHA SP.; SPIRIFER DELTHYRIS
419
428
432 ATRYPA DEVONIANA WEBSTER; CYRTINA BILLINGSI MEEK
LEPTODESMA SP.; LINGULA CF. LIGEA HALL
445
446 ATRYPA DEVONIANA WEBSTER
LEPTODESMA SP.; LINGULA CF. LIGEA HALL
460 FISH PLATES; LEPTODESMA SP.
LINGULA CF. LIGEA HALL; TENTACULITES MACKENZIENSIS KINDLE.
478 ATRYPA DEVONIANA WEBSTER; NAUTILOIDS-ORTHOCERAS TYPE
EUOMPHALUS SP.; EURYZONE SP.
485
487
490
500
250
265 ATRYPA DEVONIANA WEBSTER; FISH PLATES
290 FISH PLATES; CRINOID STEMS
STROPHEODONTA CF. NAVALIS SWALLOW
300 STROPHEODONTA CF. CALLAWAYENSIS SWALLOW
330 ATRYPA DEVONIANA WEBSTER; STROPHEODONTA SP.
340 CRINOID STEMS; TROCHILISCIDS
370 ATRYPA DEVONIANA WEBSTER
390 ATRYPA DEVONIANA WEBSTER; LEPTODESMA SP.
SPIRORBIS OMPHALOIDES GOLDFUSS
400
420
450 ATRYPA DEVONIANA WEBSTER; CYRTINA BILLINGSI MEEK
460 ATRYPA DEVONIANA WEBSTER; CYRTINA BILLINGSI MEEK
470 ATRYPA CF. GREGERI (STRAIGHT-BEAKED)
LEPTODESMA SP.; LINGULA CF. LIGEA HALL
480 ATRYPA ALBERTENSIS WARREN
ATHYRIS SP.; MODIOMORPHA SP.
490 LINGULA CF. LIGEA HALL
TENTACULITES MACKENZIENSIS KINDLE
496 TENTACULITES MACKENZIENSIS KINDLE
500
510 TENTACULITES MACKENZIENSIS KINDLE; LEPTODESMA SP.
515
ATRYPA ALBERTENSIS WARREN; NAUTILOIDS
GASTROPOD - DIAPHOROSTOMA TYPE

SIS — MACDONALD W.D. 1947 •

# TABLE No. 2
## CORRELATION OF THE WATERWAYS FORMATION WITH PORTAGE-NAPLE AGE IN OTHER PARTS OF NORTH AMERICA

• TO ACCOMPANY M. SC. THESIS — MACDONALD W.D. 1947 •

| | LOCATION OF SECTION | INDUSTRIAL MINERALS LTD No. 1 WELL WATERWAYS ALBERTA 1936 | WATERWAYS AREA COLLECTION BY DR. J.A. ALLAN AND DR. K.A. CLARK. OF THE UNIVERSITY OF ALBERTA | ALBERTA GOVT SALT WELL No. 1 (McMURRAY)<br>IND. MIN. LTD. SALT WELL No. 1 (WATERWAYS)<br>IND. MIN. LTD. SALT WELL No. 3 (WATERWAYS) | AT PEACE POINT ON THE PEACE RIVER IN ALBERTA | SIMPSON SHALE ON MACKENZIE RIVER, FIVE MILES ABOVE RABBIT SKIN RIVER. |
|---|---|---|---|---|---|---|
| | REFERENCE | ALLAN, J.A. (1943): ROCK SALT DEPOSIT AT WATERWAYS ALBERTA: RES. COUNCIL OF ALTA RPT. No. 34 p. 45 | WARREN, P.S. (1933): THE AGE OF THE DEVONIAN LIMESTONE AT McMURRAY ALTA.: CAN. FIELD NAT. VOL. 47 p. 148 | MACDONALD W.D. MASTERS THESIS 1947 | KINDLE, E.M. (1928): THE OCCURRENCE AND CORRELATION OF A DEVONIAN FAUNA FROM PEACE RIVER ALTA: G.S.C. MUS. BULL No. 47 p. 16 | KINDLE, E.M. (1919): THE DISCOVERY OF A PORTAGE FAUNA IN THE MACKENZIE RIVER VALLEY: G.S.C. MUS. BULL. No. 29 p. 2 |
| | LITHOLOGY | MOTTLED LIMESTONES; ARG. LS. CALCAREOUS SHALE | MOTTLED LIMESTONE; ARGILLACEOUS LS. CALCAREOUS SHALE | MOTTLED LIMESTONE; ARGILLACEOUS LS. CALCAREOUS SHALE | BLUE SHALE AND THIN BEDDED LIMESTONES | GREENISH TO BLUISH GREY SHALE |
| PORTAGE-NAPLES • FAUNA AND FLORA • UPPER DEVONIAN | | ATRYPA RETICULARIS (LINN)<br>CYRTINA BILLINGSI MEEK<br>LINGULA SPATULATA VAUX<br>SCHIZOPHORIA STRIATULA (SCHLOT)<br>SPIRIFER CF. TULLIA HALL<br>STROPHEODONTA DEMISSA (CONRAD)<br>STROPHEODONTA SP. | ATHYRIS ANGELICA VAR. OCCIDENTALIS WHITEAVES<br>ATRYPA RETICULARIS (LINN)<br>ATRYPA GREGERI ROWLEY<br>ATRYPA SPINOSA HALL<br>AVICULOPECTEN CF. FLABELLUM (CONRAD)<br>CHONETES SP.<br>CYRTINA BILLINGSI MEEK<br>CYRTINA HAMILTONENSIS HALL?<br>MODIOMORPHA SP.<br>PARACYCLAS ELLIPTICA HALL<br>PRODUCTELLA CALLAWAYENSIS SWALLOW<br>PRODUCTELLA HALLANA WALCOTT<br>PUGNAX PUGNUS (MARTIN)<br>SCHIZOPHORIA STRIATULA (SCHLOT)<br>SPIRIFER CF. TULLIA HALL<br>SPIRORBIS OMPHALOIDES GOLDFUSS<br>STROPHEODONTA DEMISSA (CONRAD)<br>STROPHEODONTA INEQUIRADIATA HALL<br>STROPHEODONTA INFLEXA SWALLOW<br>STROPHEODONTA PERPLANA (CONRAD)<br>STROPHEODONTA SUBDEMISSA HALL | ALGAE<br>ATHYRIS SP.<br>ATRYPA ALBERTENSIS WARREN<br>ATRYPA DEVONIANA WEBSTER<br>ATRYPA GREGERI ROWLEY<br>ATRYPA RETICULARIS LINN<br>BRYOZOA<br>CONODONTS<br>CHONETES SP.<br>CRANIA FAMELICA H. & W.<br>CRINOID STEMS<br>CYRTINA BILLINGSI MEEK<br>EUOMPHALUS SP.<br>EURYZONE SP.<br>FISH PLATES<br>FISH JAW.<br>GLYPTASPIS PLATES<br>LEPTODESMA SP.<br>LINGULA CF. LIGEA HALL<br>LEDA?<br>MODIOMORPHA SP.<br>NAUTILOIDS – ORTHOCERAS TYPE<br>ORBICULOIDEA SP.<br>PACHYPORA TYPE CORAL<br>PARACYCLAS ELLIPTICA HALL<br>PLANT FRAGMENTS<br>PRODUCTELLA SP.<br>PUGNAX PUGNUS (MARTIN)<br>RHOMBOPURA SP.<br>SCHIZOPHORIA CF. IOWENSIS HALL<br>SPIRIFER ALLANI WARREN<br>SPIRIFER DELTHYRIS<br>SPIRORBIS OMPHALOIDES GOLDFUSS<br>STROPHEODONTA DEMISSA (CONRAD)<br>STROPHEODONTA INEQUIRADIATA HALL<br>STROPHEODONTA CALLAWAYENSIS SWALLOW<br>STROPHEODONTA<br>STROPHEONELLA SP.<br>STYLIOLINA FISSURELLA HALL<br>TENTACULITES MACKENZIENSIS KINDLE<br>TROCHILISCIDS | ATRYPA RETICULARIS (LINN)<br>ATRYPA SPINOSA HALL<br>AULOPORA CF. ADENSCENS FENTON<br>CAMAROTOECHIA SP.<br>CRANIA SP.<br>CRINOID STEMS<br>CYRTINA BILLINGSI MEEK<br>CYRTINA HAMILTONENSIS HALL VAR<br>CYRTINA BILLINGSI VAR. SYMMETRICA KINDLE<br>LEDA CF. DIVERSA (HALL)<br>LEPTODESMA CF. NAVIFORME HALL<br>LEIORHYNCHUS MESACOSTALE HALL<br>MODIOMORPHA SP. UNDET<br>PALAEONEILA FILOSA (CONRAD)<br>PUGNAX PUGNUS MARTIN VAR.<br>SCHIZOPHORIA STRIATULA (SCHLOT)<br>SPIRIFER TULLIA VAR. WHITEAVES<br>SPIRORBIS OMPHALOIDES GOLDFUSS<br><br>CORRELATES WITH THE ITHICA SECTION OF NEW YORK. | BUCHIOLA RETRIOSTRIATA<br>CYRTINA GLABRA N. SP.<br>ENTOMIS SERRATO STRIATA<br>ENTOMIS VARIOSTRIATA<br>PARACARDIUM DORIS?<br><br>• ELEVEN MILES BELOW OLD FORT WRIGLEY N.W.T. ON MACKENZIE RIVER •<br>DARK LEAD-GREY SOFT SHALES<br>BACTRITES ACICULUM<br>BUCHIOLA DILATA N. SP.<br>BUCHIOLA RETRIOSTRIATA<br>ONTARIA CLARKEI<br>PARAPTYX CF. ONTARIO<br>STYLIOLINA FISSURELLA<br>TENTACULITES MACKENZIENSIS N. SP.<br><br>CORRELATES WITH THE NEW YORK PORTAGE SECTION AND UPPER DEVONIAN OF EUROPE |

| SIMPSON SHALE ON MACKENZIE RIVER, FIVE MILES ABOVE RABBIT SKIN RIVER. | FORT CREEK SHALE, BEAR MOUNTAIN NORTH WEST TERRITORIES NEAR FORT NORMAN | NORMAN WELLS AREA | SOUTH NAHANNI-LIARD RIVER AREA | UPPER PEACE RIVER VALLEY AREA | ROCHE MIETTE, JASPER PARK ALBERTA SECTION BELOW BLACKFACE MT. SHALE |
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| KINDLE, E.M. (1919): THE DISCOVERY OF A PORTAGE FAUNA IN THE MACKENZIE RIVER VALLEY: G.S.C. MUS. BULL. N°29 p.2 | KINDLE, E.M. & BOSWORTH, T.O. (1920): OIL BEARING ROCKS OF THE LOWER MACKENZIE RIVER VALLEY: G.S.C. SUMM. RPT. p. 486 | HUME, G.S. & LINK, T.A. (1945): CANOL GEOLOGICAL INVESTIGATIONS: G.S.C. PAPER 45-16 pp. 31-34 | CAMERON, A.E. & WARREN, P.S (1938): GEOLOGY OF SOUTH NAHANNI RIVER, N.W.T. CAN. FIELD NAT. VOL. 52, N°2 p. 18 | WILLIAMS, M.Y. AND BOCOCK, J.B. (19[illegible] | ALLAN, WARREN, RUTHERFORD (1932): A PREL. STUDY OF THE EASTERN RANGES OF THE ROCKY MTS. IN JASPER PARK: TRANS. R.S.C. VOL. 26, SEC IV p 236 |
| GREENISH TO BLUISH GREY SHALE | BLACK BITUMINOUS FISSLE SHALES | DARK BITUMINOUS SHALES | FOSSILIFEROUS LIMESTONE AND BARREN UNDERLYING CALCAREOUS SHALE | LIMESTONE | LIMESTONE BEDS |
| BUCHIOLA RETRIOSTRIATA<br>CYRTINA GLABRA N.SP.<br>ENTOMIS SERRATO STRIATA<br>ENTOMIS VARIOSTRIATA<br>PARACARDIUM DORIS? | CHONETES SP<br>CONODONTS<br>FOSSIL PLANTS<br>LEIORHYNCHUS SP.<br>PRODUCTELLA SP.<br>STYLIOLINA FISSURELLA<br>TENTACULITES<br><br>CORRELATES WITH THE SIMPSON SHALE | • OUTARATOU RIVER •<br>LEIORHYNCHUS CASTANEA<br>• BLUEFISH WELL N°1, BEAR ROCK •<br>BUCHIOLA SP.<br>• HUNGRY LAKE - PEEL RIVER AREA •<br>CLADOPORA<br>FAVOSITES<br>ALVEOLITES<br>ACERVULARIA<br>CYSTIPHYLLUM<br>LINGULA<br>TENTACULITES<br>CONULARIA<br><br>STELCK CORRELATES WITH FORT CREEK SHALES | ATHYRIS SP.<br>ATRYPA RETICULARIS (LINN)<br>CAMAROTOECHIA SP.<br>LEIORHYNCHUS SP. NOV.<br>SCHUCHERTELLA CHEMUNGENSIS (CONRAD)<br>SPIRIFER CF. TULLIA HALL<br><br>CORRELATES WITH OTHER UPPER DEVONIAN LOCALITIES IN MACKENZIE RIVER BASIN | ACERVULARIA RUGOSA (E. & H)<br>AMBOCOELIA CF NANA<br>ATRYPA ASPERA SCHLOT<br>ATRYPA RETICULARIS (LINN)<br>ATRYPA SPINOSA HALL<br>CHONOPHYLLUM MAGNIFICUM BILLINGS?<br>CYSTIPHYLLUM VESICULOSUM GOLDFUS.<br>EATONIA PECULIARIS (CONRAD)<br>EUOMPHALUS SP.<br>FAVOSITES BASALTICA GOLDFUSS?<br>FAVOSITES NITELLA WINCHELL<br>GYPIDULA GALEATA (DALMAN)?<br>PARACYCLAS ELLIPTICA HALL<br>PRODUCTELLA SPINULICOSTATA HALL<br>PROETUS HALDMANI HALL?<br>ROMINGERIA UMBELLIFERA BILLINGS?<br>SPIRIFER DISJUNCTUS SOWERBY<br>SYRINGOPORA SP.<br>TENTACULITES ATTENUATUS HALL?<br><br>CORRELATES WITH MIDDLE DEVONIAN BUT SEEMS MOSTLY PORTAGE. | ATHYRIS FULTONENSIS SWALLOW?<br>ATRYPA MISSOURIENSIS MILLER<br>ATRYPA SPINOSA HALL<br>BACTRITES ACICULUM HALL<br>BUCHIOLA RETRIOSTRIATA VON BUCH<br>CHONETES SP. UNDET<br>HONEOYEA SP.<br>LEIORHYNCHUS CF GLABER KINDLE<br>LEIORHYNCHUS ATHABASKENSE KINDLE<br>LOXOPTERIA LAEVIS FRECH?<br>MANTICOCERAS CF OXYCLARK<br>MARTINIA MAIA (BILLINGS)?<br>ORTHOCERAS SP.<br>PRODUCTELLA SHUMARDIANA HALL<br>PRODUCTELLA CF SPINULICOSTATA HALL<br>PROTOKIONOCERAS SP.<br>SCHIZOPHORIA STR[illegible]ULA SCHLOT.<br>SCHUCHERTELLA AR[illegible]OSTRIATA HALL?<br>SPIRIFER JASPERENSIS WARREN<br><br>BACTRITES AND BUCHIOLA ARE NAPLES FAUNA — CORRELATES WITH SIMPSON SHALE. |
| • ELEVEN MILES BELOW OLD FORT WRIGLEY N.W.T ON MACKENZIE RIVER •<br>DARK LEAD-GREY SOFT SHALES<br>BACTRITES ACICULUM<br>BUCHIOLA DILATA N. SP.<br>BUCHIOLA RETRIOSTRIATA<br>ONTARIA CLARKEI<br>PARAPTYX CF. ONTARIO<br>STYLIOLINA FISSURELLA<br>TENTACULITES MACKENZIENSIS N.SP.<br><br>CORRELATES WITH THE NEW YORK PORTAGE SECTION AND UPPER DEVONIAN OF EUROPE | | | | | |

| ROCHE MIETTE, JASPER PARK ALBERTA<br>SECTION BELOW BLACKFACE MT. SHALE | OTHER ROCHE MIETTE FAUNA<br>DIFFERENT COLLECTIONS | BANFF ALBERTA SECTION<br>LOWER HALF OF MINNEWANKA LIMESTONE | NORDEGG ALBERTA | CROWSNEST PASS AREA | ROBERTS MOUNTAIN REGION<br>NEVADA<br>DEVIL'S GATE FORMATION |
|---|---|---|---|---|---|
| ALLAN, WARREN, RUTHERFORD (1932): A PREL. STUDY OF THE EASTERN RANGES OF THE ROCKY MTS. IN JASPER PARK:<br>TRANS. R.S.C. VOL. 26, SEC IV p 236 | | WARREN, P.S. (1927): BANFF AREA ALTA.:<br>G.S.C. MEMOIR. 153 | WARREN, P.S. (1933): A MIDDLE DEVONIAN FAUNA AT NORDEGG ALBERTA:<br>CAN. FIELD NAT. VOL. 46, No. 11, p 184 | WARREN, P.S. (1928): THE PALEOZOICS OF THE CROWSNEST PASS ALBERTA:<br>TRANS. R.S.C. VOL. 22 SECT. IV pp 112-113 | MERRIAM, C.W. (1940): DEVONIAN OF THE ROBERTS MOUNTAINS REGION NEVADA:<br>G.S.A. SPEC. PAPER No. 25 p. 60 |
| LIMESTONE BEDS | LIMESTONE | LIMESTONE | LIMESTONE | LIMESTONE | LIME STONES |
| ATHYRIS FULTONENSIS SWALLOW?<br>ATRYPA MISSOURIENSIS MILLER<br>ATRYPA SPINOSA HALL<br>BACTRITES ACICULUM HALL<br>BUCHIOLA RETRIOSTRIATA VON BUCH<br>CHONETES SP. UNDET<br>HONEOYEA SP.<br>LEIORHYNCHUS CF GLABER KINDLE<br>LEIORHYNCHUS ATHABASKENSE KINDLE<br>LOXOPTERIA LAEVIS FRECH?<br>MANTICOCERAS CF OXYCLARK<br>MARTINIA MAIA (BILLINGS)?<br>ORTHOCERAS SP.<br>PRODUCTELLA SHUMARDIANA HALL<br>PRODUCTELLA CF SPINULICOSTATA HALL<br>PROTOKIONOCERAS SP.<br>SCHIZOPHORIA STRIATULA SCHLOT.<br>SCHUCHERTELLA ARCTOSTRIATA HALL?<br>SPIRIFER JASPERENSIS WARREN<br><br>BACTRITES AND BUCHIOLA ARE NAPLES FAUNA — CORRELATES WITH SIMPSON SHALE. | • WARREN, P.S. COLLECTION •<br>ATRYPA MISSOURIENSIS MILLER<br>ATRYPA RETICULARIS (LINN)<br>ATRYPA SPINOSA HALL<br>AULOPORA SP.<br>CHONETES DEFLECTA HALL<br>CLADOPORA SP.<br>CYATHOPHYLLUM SP.<br>CYRTIA? ROCKYMONTANA WARREN<br>DIPHYPHYLLUM COLEMANENSE WARREN<br>GYPIDULA CF. CORNUTA FENTON<br>LEIORHYNCHUS ALBERTENSIS WARREN<br>LEIORHYNCHUS CF. GLABER KINDLE<br>PRODUCTELLA HALLANA WALCOTT<br>SCHIZOPHORIA STRIATULA SCHLOT.<br><br>• BURGESS (4) COLLECTION, IN BLACK SHALE •<br>BACTRITES GRACILLIOR CLARKE<br>BUCHIOLA RETRIOSTRIATA VON BUCH<br>ENTOMIS VARIOSTRIATA CLARKE<br>EUTHYDESMA SUBTEXTILE HALL<br>LINGULA MELIE HALL<br>STYLIOLINA FISSURELLA HALL<br>TENTACULITES SCALARIFORMIS HALL<br>TORNOCERAS BICOSTATUM HALL<br><br>• NAPLES FAUNA •<br>• RAYMOND, P.E. (57) ADDITIONAL FAUNA •<br>CONULARIA SP.<br>SPIRIFER ENGELMANNI MEEK<br>ONTARIA SP.<br>POSIDONIA CF. ATTICA (WILLIAMS)<br>CYRTINA SP.<br>PUGNAX MINATUS WARREN | ACERVULARIA ?<br>ATRYPA MISSOURIENSIS MILLER<br>CHONETES DEFLECTA HALL<br>DIPHYPHYLLUM COLEMANENSE WARREN<br>FAVOSITES LIMITARIS ROMINGER<br>FAVOSITES SP.<br><br>CORRELATES WITH ROCHE MIETTE JASPER PARK. | PRODUCTELLA HALLANA<br>ATRYPA RETICULARIS VAR A KINDLE<br>MARTINIA NEVADENSIS WALCOTT<br><br>WARREN, P.S. (1942): THE SPIRIFER ARGENTARIUS FAUNA OF THE CANADIAN ROCKIES:<br>TRAN. R.S.C. VOL. 36, SEC IV p. 133<br>SPIRIFER JASPERENSIS WARREN<br>ENTONIS SERRATOSTRIATA SANDBERGER | ATRYPA MISSOURIENSIS MILLER<br>ATRYPA RETICULARIS (LINN)<br>ATRYPA SPINOSA HALL<br>CHONETES DEFLECTA HALL<br>CYRTIA? ROCKYMONTANA WARREN<br>DIPHYPHYLLUM COLEMANENSE WARREN<br>LEIORHYNCHUS ALBERTENSE WARREN<br>LINGULA SPATULATA VANUX<br>PRODUCTELLA HALLANA WALCOTT<br>SCHIZOPHORIA STRIATULA SCHLOT.<br>SPIRIFER JASPERENSIS WARREN<br><br>THIS PARTIAL LIST CORRELATES WITH THE BANFF AND ROCHE MIETTE FAUNAS. | ATRYPA CF. MONTANENSIS KINDLE<br>ATRYPA RETICULARIS (LINN)<br>ATRYPA SP.<br>CHONOPHYLLUM SP.<br>CLADOPORA SP.<br>CYATHOPHYLLUM SP.<br>DIPHYPHYLLUM FASCICULUM MEEK<br>EUOMPHALUS SP.<br>HYPOTHYRIDINA EMMONSI (H&W)<br>LOXONEMOID GASTROPODS<br>PHILLIPSASTRAEA SP.<br>PARACYCLAS SP.<br>PRODUCTELLA SP.<br>PUGNAX SP.<br>SPIRIFER ARGENTARIUS MEEK<br>SYRINGOPORA SP. |

| ROBERTS MOUNTAIN REGION NEVADA DEVIL'S GATE FORMATION | SNYDER CREEK SHALE OF MISSOURI | ANTRIM BLACK SHALE MICHIGAN | KETTLE POINT BLACK SHALE ON LAKE HURON, ONTARIO | LONG RAPIDS FORMATION HUDSON BAY REGION | ALBERTA PACIFIC CONSOLIDATED OILS. LTD. WELL DUVERNAY, ALBERTA |
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| MERRIAM, C.W. (1940): DEVONIAN OF THE ROBERTS MOUNTAINS REGION NEVADA: G.S.A. SPEC. PAPER No. 25 p. 60 | BRANSON, E.B. (1922): THE DEVONION OF MISSOURI: MISSOURI BUREAU OF GEOL. AND MINES, VOL. 17 2ND SEC. pp. 41-42 | WARTHIN, A.S & COOPER, G.A. (1942): COOPER ET.AL. - CORRELATION OF THE DEVONIAN OF NORTH AMERICA: G.S.A. BULL. VOL. 53 p. 1744 | STAUFER, C.R. (1915): THE DEVONIAN OF SOUTHWEST ONTARIO: G.S.C. MEMOIR 34, pp. 226-227 | KINDLE, E.M. (1923): GEOLOGY OF NORTHERN PART OF MOOSE RIVER BASIN ONTARIO: G.S.C. SUMM. RPT. PT C1 pp 35-36 | WARREN, P.S. (1933): THE AGE OF THE DEVONIAN LIMESTONE AT McMURRAY ALBERTA: CAN. FIELD NAT. VOL. 47, p. 149 |
| LIMESTONES | DRAB SHALE AND LIMESTONE | BLACK SHALE, GREENISH BEDS AT BASE. | BLACK SHALE UNDERLAIN BY BLUE LIMESTONES AND SHALES. | BLACK SHALE AND BLUE GREY ARGILLACEOUS SHALE | GREY-BROWN LIMESTONES AND GREEN-GREY SHALES |
| ATRYPA CF. MONTANENSIS KINDLE<br>ATRYPA RETICULARIS (LINN)<br>ATRYPA SP.<br>CHONOPHYLLUM SP.<br>CLADOPORA SP.<br>CYATHOPHYLLUM SP.<br>DIPHYPHYLLUM FASCICULUM MEEK<br>EUOMPHALUS SP<br>HYPOTHYRIDINA EMMONSI (H.&W.)<br>LOXONEMOID GASTROPODS<br>PHILLIPSASTRAEA SP.<br>PARACYCLAS SP.<br>PRODUCTELLA SP<br>PUGNAX SP.<br>SPIRIFER ARGENTARIUS MEEK<br>SYRINGOPORA SP. | ATHYRIS FULTONENSIS SWALLOW<br>ATRYPA GREGERI ROWLEY<br>ATRYPA RETICULARIS (LINN)<br>ATRYPA SPINOSA HALL<br>BELLEROPHON SP.<br>CAMAROTOECHIA DEPRESSA KINDLE<br>CAMAROTOECHIA GREGERI BRANSON<br>CHONOPHYLLUM ELLIPTICUM H.&W.<br>CRANIA FAMELICA H.&W.<br>CYRTINA TRIQUETRA HALL<br>CYRTOCERAS SP.<br>DIAPHOROSTOMA SNYDERENSIS BRANSON<br>EURYZONE SP<br>EUOMPHALUS CF. HECALE HALL<br>GLYPTASPIS SP.<br>GRAMMYSIA ELLIPTICA HALL<br>MODIOMORPHA MISSOURIENSIS BRANSON<br>NAUTILUS LAWSII SWALLOW<br>NUCULA CF. LIRATA (CONRAD)<br>ORTHOCERA SP.<br>ORBICULOIDEA SP.<br>PARACYCLAS ELLIPTICA HALL<br>PARACYCLAS LIRATA (CONRAD)<br>PENTAMERELLA MISSOURIENSIS BRANSON<br>PLEUROTOMARIA ISAACSI H.&W.<br>PRODUCTELLA CALAWAYENSIS SWALLOW<br>SCHIZOPHORIA STRIATULA (SCHLOT.)<br>SPIRIFER ANNAE SWALLOW<br>SPIRIFER EURYTEINES OWEN<br>STROPHEODONTA CALLAWAYENSIS SWALLOW<br>STROPHEODONTA DEMISSA (CONRAD)<br>STROPHEODONTA EQUICOSTATA SWALLOW<br>STROPHEODONTA NAVALIS SWALLOW<br>STROPHEONELLA CRASSA ROWLEY<br>STROMATOPORA SOLIDULA H.&W.<br>SPIRORBIS OMPHALOIDES GOLDFUSS | BARROISELLA SUBSPATULATA M.&W.<br>BUCHIOLA SP.<br>CONODONTS<br>PARACARDIUM SP.<br>SPORANGITES<br>STYLIOLINA SP.<br>TORNOCERAS SP.<br><br>— OLENTANGY SHALE · CENTRAL OHIO —<br>BAKER, R.C. (1942): AGE AND FOSSILS OF THE OLENTANGY SHALE: AMER. JOUR. SCI., VOL. 240, p. 140<br>BLUE-GREY ARGILLACEOUS SHALE<br>AMBOCOELIA UMBONATA (CONRAD)?<br>ANAPTYCHUS? EMERSONI (CLARKE)<br>CONODONTS<br>CHONETES MINUTUS HEMISPHERICUS, N. VAR.<br>CRANIA SP.<br>FISH FRAGMENTS<br>HEDERELLA SP.<br>LEIORHYNCHUS SP.<br>LINGULA SP.<br>MANTICOCERAS SP.<br>MELOCRINUS CLARKEI WILLIAMS<br>NUCULA SP.<br>ORBICULOIDEA SP.<br>ORTHOCERAS SP.<br>PLEUROTOMARIA SP.<br>SPORANGITES<br>STRAPAROLLUS CF. HECALE HALL<br>TENTACULITES GRACILISTRIATUS HALL<br>TORNOCERAS UNIANGULARE (CONRAD)?<br><br>CORRELATES WITH PORTAGE OF NEW YORK. | CONODONTS<br>FISH PLATES<br>LINGULA CF. LIGEA HALL<br>LINGULA SPATULATA VANUX<br>ORBICULOIDEA SP.<br><br>· STAUFFER'S HAMILTON FAUNA OF OLENTANGY SHALE, WIDDER BEDS ·<br>AMBOCOELIA UMBONATA (CONRAD)<br>ATHYRIS SPIRIFEROIDES EATON<br>ATHYRIS VITTATA HALL<br>ATRYPA RETICULARIS (LINN)<br>BACTRITES ARKONENSIS WHITEAVES<br>CHONETES DEFLECTA HALL<br>CYSTIPHYLLUM VESICULOSUM GOLDFUSS<br>CYRTINA HAMILTONENSIS HALL<br>HEDERELLA SP.<br>LEDA ROSTELLATA (CONRAD)<br>ORTHOCERAS ERIENSE HALL<br>PARACYCLAS LIRATA (CONRAD)<br>PHACOPS RANA GREEN<br>SCHIZOPHORIA STRIATULA (SCHLOT)<br>SPIRIFER MUCRONATUS (CONRAD)<br>SPIRORBIS OMPHALOIDES GOLDFUSS<br>STROPHEODONTA DEMISSA (CONRAD)<br>SYRINGOPORA NOBILIS BILLINGS<br>STYLIOLINA FISSULELLA HALL<br>TENTACULITES ATTENUATUS HALL<br>TORNOCERAS UNIANGULARE (CONRAD) | CONODONTS<br>LINGULA SPATULATA VANUX<br>PUGNAX PUGNUS (MARTIN)<br>SPORANGITES<br><br>CORRELATES WITH KETTLE POINT AND OLENTANGY SHALES<br><br>— IMPERIAL RIBSTONE No. 1 WELL RIBSTONE ALBERTA —<br>HUME, G.S. & HAGE, C.O. (1941): THE GEOLOGY OF EAST CENTRAL ALBERTA: G.S.C. MEMOIR 232, p. 10<br>GREEN SHALE AND GREY LIMESTONE<br>ATHYRIS SP.<br>ATRYPA RETICULARIS (LINN)<br>BUCHANOPSIS SP.<br>CRINOID STEMS<br>CYRTIA STANDLYENSIS?<br>CYRTINA CF. HAMILTONENSIS HALL<br>NUCULA SP.<br>SPIRIFER CF. ALBIPINENSIS<br>SPIRORBIS SP.<br>STRAPAROLLUS CF. QUADRIVALVUS<br>TREMATOPORA SP. | BUCHIOLA RETRIOSTRIATA VON BUCH<br>LINGULA SPATULATA VANUX<br>TENTACULITES MACKENZIENSIS KINDLE<br><br>CORRELATES WITH THE WATERWAYS FAUNA<br><br>· WATERWAYS FAUNA IN WELLS FROM WATROUS, SASKATCHEWAN TO VERMILION, ALBERTA ·<br>ATHYRIS SP.<br>ATRYPA DEVONIANA WEBSTER<br>ATRYPA ALBERTENSIS WARREN<br>BRYOZOA<br>CRINOID STEMS<br>FISH FRAGMENTS<br>LINGULA SPATULATA VANUX.<br>SPIRIFER ALLANI<br>SPIRIFER CF. EURYTEINES OWEN?<br>STROPHEODONTA SP.<br>STROPHEODONTA INEQUIRADIATA HALL<br>STROPHEODONTA CF. BOONENSIS SWALLOW?<br>TENTACULITES MACKENZIENSIS KINDLE<br><br>CORRELATES WITH THE WATERWAYS AND SNYDER CREEK FORMATIONS. |

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